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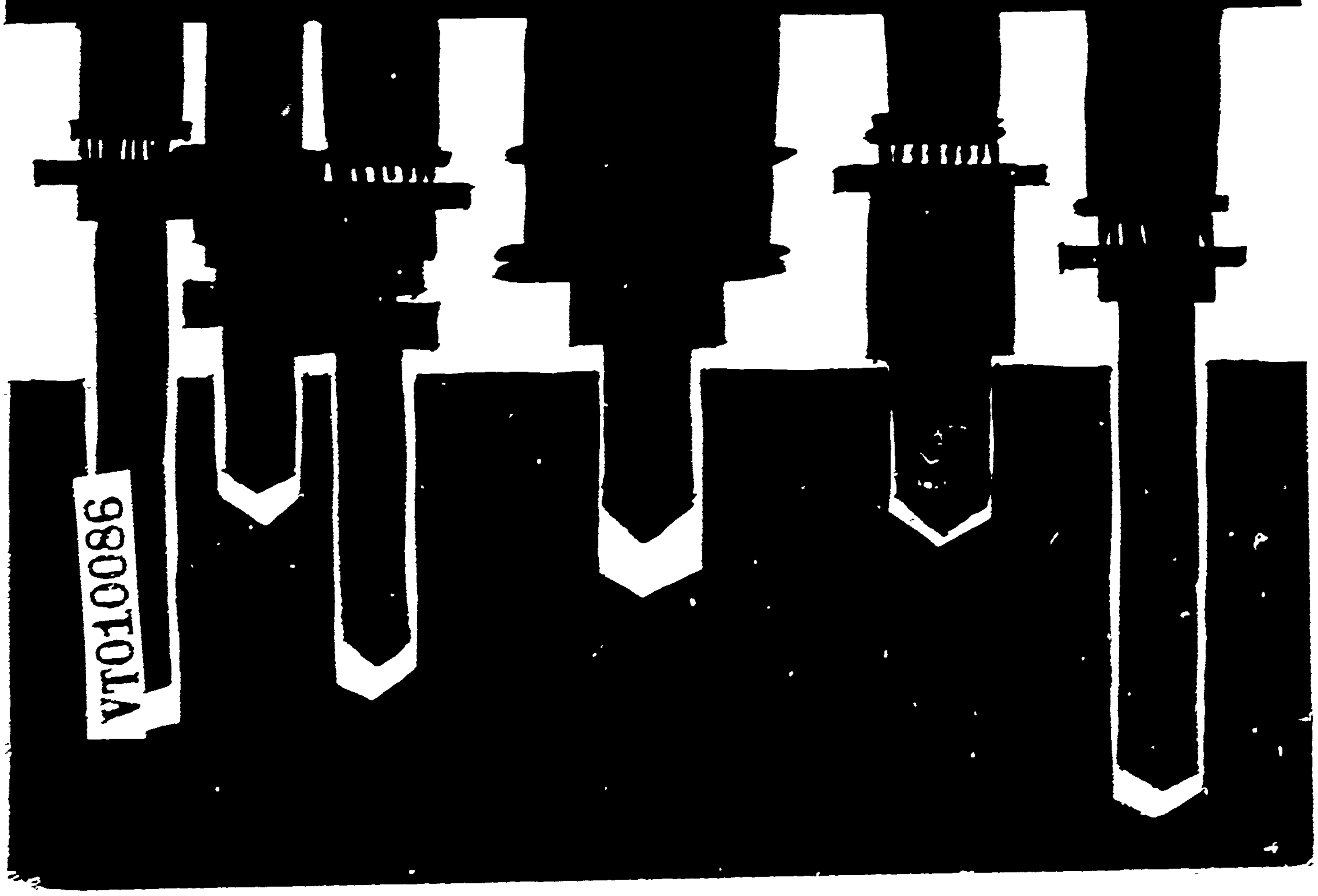
ABSTRACT

At the present time, only 5 percent of the short-run metal-cutting machining in the United States is done by numerically controlled machined tools, but within the next decade it is expected to increase by 50 percent. Numerically controlled machines use taped data which is changed into instructions and directs the machine to do certain steps automatically and then test its own performance. This report compares requirements for operators of numerically controlled machines with conventional machines in terms of training, experience, aptitudes, interests, temperaments, physical demands, and working conditions, and discusses the implications of automatic drafting machines, digitizing machines, computer programing, manual parts programing, tool design and presetting, and program, tooling, and tape testing for the industry. The second part of the study provides job descriptions for department planning, part programing, tool presetting, electronics maintenance, and 3 categories of operators which include job machine boring, milling machine, and vertical turret lathe operators. A glossary of terms and a bibliography are appended. (BC)

technical report on

OCCUPATIONS IN NUMERICALLY CONTROLLED METAL-CUTTING MACHINING

U.S. DEPARTMENT OF LABOR
Manpower Administration



technical report on OCCUPATIONS IN NUMERICALLY CONTROLLED METAL-CUTTING MACHINING

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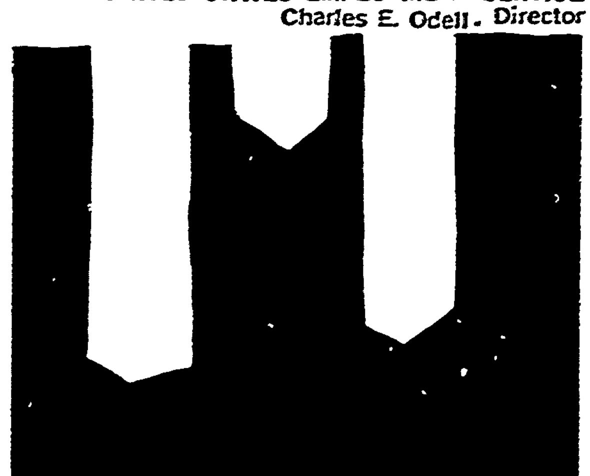

SPECIAL NOTICE

The occupational descriptions contained in this volume have been compiled from a number of different sources and therefore describe the individual occupations in a generalized composite form. Consequently, no description can be expected to coincide exactly with any specific job in a particular establishment or in a particular locality. To be of greatest usefulness, the descriptions should be supplemented by local information concerning the specific jobs in the community.

The U. S. Employment Service has no responsibility for the settling of jurisdictional matters or the setting of wages and hours. In the preparation of occupational descriptions, no facts concerning such matters were collected. It should be clearly understood, therefore, that, because of their nature, occupational descriptions published by the U. S. Employment Service cannot be considered standards for the determination of wages, hours, or jurisdictional matters.

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FOREWORD

Metalworking, as a manufacturing process, is of great importance in many of today's industries. Its occupations are undergoing tremendous changes with numerically controlled metal-cutting machining advances. Intensive attempts to apply new developments in automatic control theory and electronics to machining processes started about 20 years ago, and the first practical numerically controlled machine tools were put in use in 1957. Now there are almost 10,000 numerically controlled machine tools in use, and both the number of these machines and their proportion to conventional machine tools are expected to continue increasing over the next few years.

Studies conducted by industrial groups, business consultants, and others indicate the possibility that almost 50 percent of all short-run metal-cutting machining in the United States will be accomplished on numerically controlled machine tools within the next decade as compared to under 5 percent at the present time. Rapid acceptance of numerical control makes necessary an awareness of its implications for the work force of today and tomorrow, and an understanding of the changing education, experience, and training-retraining requirements the new technology is imposing.

The primary purpose of this booklet is to present this kind of occupational information for use in counseling, placement, and other manpower activities of the State Employment Services. It also will be useful to others concerned with recruitment, training, and counseling of persons in this field of work.

CHARLES E. ODELL
Director,
U.S. Employment Service

INTRODUCTION

WHAT IS NUMERICAL CONTROL?

Numerical control means the control of all or a part of any process by introducing programed symbolic instructions and numerical data, with at least some portion of the control incorporating feedback (self-correction). The utilization of this technique results in making a process highly automatic and accurate. Basically, the numerically controlled machine converts taped data into instructions, which direct the machine to do certain things automatically, including a sampling of its own performance.

Process control of continuous-flow industrial processes, such as catalytic cracking of petroleum and the automated production of synthetic rubber, is generally a separate area of computer application from numerical control. Since most continuous industrial processes have so many variables requiring control, a computer is an essential central element of the automatic process-control system. Such a computer can be either special or general-purpose in design. It can also be an analog (measuring) or digital (counting) computer, or it can be a hybrid which employs characteristics of both types.

Nevertheless, a precise distinction between numerical control and process control is not possible. Numerically controlled systems for machine tools, and other discontinuous shop processes such as flame cutting, pipe bending, and welding, normally have computerlike elements, such as a limited "memory" and logic circuitry. Thus many controls, while executing a current instruction, are able to retain a previous instruction and look ahead to the next. Some controls for machine tools actually contain a special-purpose computer. These can be used to interpolate; they can compute the large number of intervening points on a circle or parabola that are needed to hold a machining operation within desired tolerances. These control systems have developed to reduce the manual computational effort in part programing. They also eliminate the need for the services of an expensive "front office" engineering or business data processing computer which might otherwise be required by the part programer working on complicated or lengthy assignments.

WHY IS NUMERICALLY CONTROLLED MACHINING IMPORTANT?

In early 1965 an estimated 500,000 workers were employed as machine tool operators. For these work forces (of which those engaged in metal-cutting machining are only a part), it is expected that thousands of job openings will occur during the 1965-75 period. Most of these will result from the need to replace experienced workers, with retirements and deaths alone providing about 25,000 openings annually.[1]

[1] Occupational Outlook Handbook, 1966-67 edition, Bureau of Labor Statistics, U.S. Department of Labor.

However, what would be a normal increase in total employment due to progress in the economy generally and greater demands for products of machine tooling will be somewhat offset by the increases in output per worker due to technological changes. Numerical control of machine tools constitutes a major technological development and as a result of a substantial increase in use of numerical control through the mid-1970's, overall manpower requirements for machine tool operators may be reduced. Conversely, additional engineers, programers, and technicians probably will be needed.[1]

Numerical control can perhaps be expected to have a greater impact on occupations related to the processes of short-run machining than any other technological change. While we seem to be living in a mass-production environment, our economy could also well be characterized as 'one great job shop.' As an example, even where "Detroit Automation" is applied, short-run and single-part machining still are needed to make these high-production lines possible. Tools, dies, jibs, fixtures, cams, templates, models, and special-purpose machines and transfer lines must be designed and produced. According to a study undertaken several years ago, about 75 percent of the machined parts made in this country were produced in lots of 50 or less[2]; and short-run machining is the manufacturing area where numerical control really comes into its own. While not as efficient in mass production operations as automatic, special-purpose machines, numerically controlled machine tools assigned to short-run jobs in many industries already are surpassing their conventional counterparts in machining economy. This is particularly true in the case of installations where management has reallocated groups of work tasks to take full advantage of numerical control's potential chipmaking (cutting away of excess metal) productivity.

Numerical control is much more than a new method. It can be described as a new concept of manufacturing management. It makes available an alternative to many conventional machining methods. Until the advent of numerical control, manufacturing engineering had to make a series of hard choices.

- Would the volume be so small that strictly manual machining would be the best choice?
- Should jigs be made, especially when repeat orders were probable?
- Would automatic machines be preferable to other methods—despite lengthy setup and change-over time?
- Might production runs be long and unvaried enough to warrant the design and installation of special-purpose machine tools and material-transfer equipment?

Numerical control makes possible some of the economic advantages of mass production manufacturing, while retaining the flexibility of machining with general purpose, non-specialized machine tools.

Frequently, numerical control can be used effectively for one-of-a-kind machining. This is particularly the case with respect to parts which

[1] America's Industrial and Occupational Manpower Requirements, January 1966, Bureau of Labor Statistics, U.S. Department of Labor.

[2] *Economics of Plant Automation.* Frank Shallenberger, New York, John Wiley, 1957. (In "Automation in Business and Industry", Eugene Grabbe, editor.)

involve high labor costs because of the use of conventional machining methods. Consider the following example: a single workpiece in which several hundred precisely located holes must be drilled.

In this case, the operator of a conventional machine understandably works more and more carefully and slowly, and his labor time on the part increases. By way of contrast, the numerically controlled machine will proceed at its predetermined and predictable speed, mindless and uncaring. Of course, the control tape prepared by the part programer had better be right!

Numerical control is also making a contribution in another area, that of machining matching parts. Using axis-reversal switches on the console, or a computer routine for the same purpose, "left hand—right hand", or mirror image, parts can be made. Thus, matching side frames of a machine can be made from only one part program. Also, dissimilar but mating parts, such as housings and their covers, can usually be produced at less cost. In situations such as these, numerical control may well be selected over conventional machining methods even though it is the more expensive machining method. This is because in the total picture of manufacturing costs, numerical control permits considerable reduction, or even elimination, of rework and corrective hand finishing at the final assembly point.

To justify investment in numerical control, an increasing number of users are reexamining conventions of manufacturing they formerly took for granted. One example is acceptance of traditional, "handbook" feedrates and speeds. Increasingly, these are being rejected, and replaced by new, optimum standards based on users' test runs on their own machine floors.

Taken alone, each minor improvement in such things as fixturing, tooling, (and tool sharpening), and fluids used to cool and lubricate parts during machining, may not be significant. Cumulatively, however, these can permit increases in machining feeds and speeds, without undue sacrifice of surface finishes, tolerances, and tool life. This is particularly so when shop machinability practices have remained almost unchanged for many years—a situation that is not unusual. Also, some managements have failed to take due notice of improved rigidity and vibration-damping characteristics of newer machine tools and the increasingly effective quality control of workpiece materials. These all permit a lower "margin of insurance" than was previously possible when manufacturing standards were being set up.

Thus the fact of commitment to numerical control as a manufacturing method has had other effects, some of them unexpected. Perhaps one of the most important of these is that the technique affords its users practice in questioning and amending customary ways of doing business, and in taking an integrated view of their operations.

As this new breed of machine tool continues to replace traditional machines and methods, the occupational implications of numerical control become more and more important to personnel involved in placement, counseling, and guidance. Not only are the machines different, but associated with them are major changes in product design, drafting, production planning, man-machine relationships, and maintenance. All of these changes directly affect occupations and their interrelationships in the many industries that are adopting numerical control.

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HISTORICAL BACKGROUND

Early numerical control development was sponsored by the U.S. Air Force. Immediately after World War II it became apparent that new manufacturing methods would be required to produce supersonic aircraft and missiles.[1] The introduction of new materials required new machining methods. New and more complex parts demanded greater accuracy and precision than operators could achieve with production machine tools or cam-following tool-room equipment such as duplicator milling machines. Machining "from the solid" of complex shapes like aircraft skin sections with integral supporting structures was necessary to meet the strength-to-weight requirements of supersonic aircraft; and it was recognized that costs of tooling and manufacturing by conventional methods would be prohibitive. Production runs usually were short, and rapid technological improvements applicable to jet aircraft and missiles shortened permissible lead time and forced frequent design changes, often at the last minute. Thus, any new method for machining new products had to be very flexible. "Detroit Automation"—the use of special-purpose machine systems for mass-production of standardized items—was not a solution to problems facing aerospace and ordnance manufacturers.

The first numerical control study and developmental contracts were placed in 1948 and 1949. Research was rapidly intensified and broadened to bring in personnel affiliated with numerous manufacturers and users of machine tools, controls, and computers, including universities. In the early 1950's, public demonstrations of a numerically controlled profile milling machine were conducted at the Servomechanisms Laboratory of the Massachusetts Institute of Technology. The Air Force placed volume orders for numerically controlled machines in 1955, and by 1957 the first machines were installed, debugged, and at work in suppliers' plants.

The development of numerical control probably is unique in that sophisticated multi-axis machines were made first available to resolve some of the "space age" problems referred to above. Less complex and expensive machines came later. Transistorized, modularized control systems were marketed only about five years ago. Numerical machine and control systems now have become economically competitive with conventional machine tools for the vast range of short-run machining work in our manufacturing economy. While numerical control is becoming more productive and reliable, comparative cost is declining. These have become major factors in the industrial acceptance of numerical control.

It seems probable that workers in the metalworking industries will find more changes in the content of their jobs in the next few years than in any previous period. Continuing developments in computer, control, and instrumentation technology, and basic research in machine tool dynamics and metallurgy are all combining to have an effect on machining methods and the occupations related to them. Such developments are also having less direct, tangible effects on the whole of manufacturing organizations that adopt them. Some of these effects are described later. These effects are the results of the application of numerical control to low production metal-cutting machining. However, some of them also may occur when numerical control is applied to other spheres of manufacturing.

[1] For those interested in more information, the following two sources are suggested: *Scientific American*, September, 1952, and *American Machinist*, October 25, 1954.

OCCUPATIONAL CHANGES AND IMPLICATIONS OF NUMERICAL CONTROL

MANUFACTURING MANAGEMENT

The "systems" approach to manufacturing planning—formal analytical study of alternative procedures and methods to define the optimum, integrated manufacturing system—is having an effect on all types of industries. Managements are being compelled to reexamine traditional organizational structures on a systematic basis. As a result, jobs are being changed both in their content as well as in their relationship to other jobs. Even jobs at the "top management" level are being altered; new analytical tools for managerial analysis and decision-making require an understanding of their usefulness.

The increasing presence of managers who have formal training in business administration, systems analysis, and operations research techniques, and a trained ability to "see the big picture" when defining operational requirements, undoubtedly has been a factor in the increasing acceptance of numerical control.

DESIGN AND MANUFACTURING PLANNING

Only recently have significant attempts been made to design products from the ground up for manufacture by numerical control. Manufacturing feasibility and cost analysis are beginning to play a major role, frequently for the first time, in the definition of optimum designs. As might be expected, the leaders in this effort are aircraft, aerospace and ordnance industries, with their years of numerical control experience. Many employers in non-defense industries are beginning to insist that their design engineering personnel acquire a considerable knowledge of numerical control processes, as well as machine capabilities and limitations. Thus, an increasing proportion of their new-products mix is being designed to take full advantage of the numerical control potential.

Current products that were originally designed for conventional machining are also being redesigned for numerical control. This trend probably has been greatly accentuated by the continued high level of our economy. since many companies have been operating at or near their full productive capacity for several years. However. one numerical control tape usually can make unnecessary one or several jigs. patterns. cams. and templates or other encumbrances of conventional machining. These can be scrapped when a part is programed for numerical control. They do not have to be stored. moved. maintained or repaired. Also. manufacturing for inventory can almost be eliminated if desired. and current inventory geared much more closely to work orders because of the shortened lead-time and inherent flexibility of numerically controlled machining. All these factors tend to release experienced workers and valuable plant space for more productive purposes.

AUTOMATIC DRAFTING MACHINES, COMPUTERS

Automatic drafting machines—basically X-Y plotters but sophisticated. often large in size. and capable of high accuracy and rapid recording speed—are coming into common use in the aircraft and aerospace industries to record digital computer output in graphic form. They are also gaining acceptance in non-defense industries: here applications appear more limited and used mostly to verify tool path data on control tapes. Drafting machines are used either directly connected to a computer or off-line and use computer output as an input medium. Sometimes camera and closed-circuit television systems are included in the drafting machine package. Some machines can scale up and down. to produce drawings to the exact scale desired. Probably the major current use of most drafting machines is in verifying the accuracy of tapes before they are released for production purposes, but there are many other applications, such as scribing, plotting, lofting and even straight drafting. The last of these may eventually have the greatest effect on personnel employed in the drafting occupations. Some of the machines now being marketed not only can develop three-view line drawings. but also have full alphabetic and numerical printing capabilities and thus can produce supporting data on drawings. However, as is the case with almost any new piece of hardware. it probably will be some time before procedures to realize the full potential of the equipment are completely developed and appreciated.

Research is continuing in computer programing for automatic drafting and in computer-assisted designing. If much of this research bears fruit. then it is possible that some, or even considerable personnel dislocation or displacement may occur. Engineering personnel involved in the development and application of automatic drafting processes express the belief that it is too early to make quantitative forecasts concerning the occupational significance of automatic drafting. It may be that just the mix of work tasks in the engineering and technical support occupations may shift, with the significant change being the take-over by computer and automatic drafting machines of some of the more tedious work tasks of various jobs. Also, automatic drafting may become most useful as an adjunct to conventional methods, rather than a replacement for them. Its greatest value may be as a tool in engineering design and analysis and

modification, rather than a tool in the preparation of drawings for production purposes.

Computer-assisted design ultimately may have a considerable impact on many professional engineering and technical-support occupations. One current system titled AED-1 (Automated Engineering Design) is aimed both at eliminating the need for engineering programing and making unnecessary the conversion of drawings to computer-processable format. With this system, the design engineer addresses the computer by drawing lines on a cathode-ray tube with a photoelectric light pen. He presses buttons and keys to define his design intent, modify portions of the design, and specify dimensions. A large-scale digital computer receives, converts, calculates, and stores the design information.

Eventually, computer-assisted design can have occupational implications far beyond the design, drafting and technical-support areas. It already is technically feasible to merge the output of the design engineer-computer team into the computerized business data processing system so that most or all of the paperwork of manufacturing can be prepared as a byproduct of the design effort. The span of control of the design engineer could be extended all the way through manufacture of the end products, when all numerically controlled manufacturing and materials-handling facilities are brought under surveillance of a centralized computer-control system. Such a total manufacturing system may never be economically feasible except in specialized and limited manufacturing areas, but it is well within the reach of present scientific and technical knowledge, and even the possibility of a factory—and its office—almost devoid of workers, raises serious socioeconomic questions.

DIGITIZING VERSUS DRAFTING MACHINES

Digitizing machines were developed to perform functions in opposition to those of drafting machines. In general, the purpose of digitizers is to sense points on drawn or scribed lines on existing drawings or patterns (instead of drawing them), and convert those points to numerical data on a paper tape or other medium. These data then can be further processed by a computer, or used directly to control machine tool movements. Thus an engineering drawing, pattern, loft plate, or similar object placed on the machine table can be the input medium.

After the operator zeros in the sensing device—with a built-in microscope on the machine, or by using a console with a closed circuit television display—he can instruct the machine to follow the rest of the line or curve by depressing console keys. On some machines he can also add instructions, such as coolant off-on commands and machine tool feedrates through the keyboard, to produce complete machining tapes, rather than tapes that merely define the configuration of parts to be machined.

Until now, the major market for digitizing machines has been the aircraft and aerospace industries. However, development of more sophisticated and flexible digitizing systems may change this situation rapidly. Now on the market, for example, are machines capable of both digitizing and drafting functions, with moderate change-over time required of the operator. These machines are becoming recognized by management

in many industries as very desirable: they add to manufacturing flexibility, and at a cost that is feasible.

Other developments, such as digital computers with multi-processing features (that can process several programs simultaneously), are also leading to increasing acceptance of digitizing and drafting machines. Multiprocessing permits the integration of the drafting/digitizing system and the computer without interfering with the computer's other, more conventional, application.

The application of techniques developed for photogrammetry (the science of reducing data from three-dimensional aerial photographs) has been under development for several years. These techniques are permitting data digitizing from three-dimensional models, rather than from loft drawings. By photogrammetric methods, the automobile industry, for example, might cut its crucial lead time in producing dies for new body designs to a small fraction of that required at present. Some automobile manufacturers have already partially automated their die-making processes,[3] taking off dimensions directly from clay models of body components by these methods, to produce tapes for contour-milling metal dies on multi-axis machines. This has the effect of eliminating much intricate, manual work such as loft line sweetening, wood mockup making, and the extensive hand finishing of dies fabricated on tracer-type duplicating machines.

COMPUTER PROGRAMING, PART PROGRAMING

Part programing personnel often use an address language that is derived from one of computer programing—FORTRAN being the current, outstanding example—but are not required to know all the details of how a computer functions, its logic and arithmetic units, and its capabilities and limitations. On the other hand, the computer programer for numerical control must know these, and well, for at least one make and type of digital computer, and also must meet most of the requirements of a part programer, in order to be able to prepare or modify numerical control computer programs effectively.

Thus, to be effective, any computer programer for numerical control must bring two things to the job. He must be an effective engineering-and-scientific computer programer, and he must have acquired a fairly extensive background in machine shop practices, machining properties of materials, and machine tool and control capabilities. The ability and experience to perform adequately in only one of the two areas is just not enough. The job is interdisciplinary in nature.

This is also an example of another factor: new jobs do not respect traditional occupational structures. Many well-experienced engineers with various educational backgrounds have been able to gain an understanding of part programing by studying manuals and taking numerical control programing courses of one or a few weeks duration.

Much the same holds true for computer programing. Many courses now are offered that provide the basics of computer programing for working engineers. Experienced engineering personnel who for many

[3] Business Week, September 11, 1965
The Iron Age, December 23, 1965

years have been away from school seldom have difficulty in understanding the concepts presented in these courses. However, they may have difficulty in applying these concepts in the technically difficult area of numerical control. The mathematics required to be a successful numerical control computer programer is different in both level and nature from what was typically available 20, or even 10 years ago. Thus, to function effectively as a computer programer for multi-axis numerical control, the older worker in the engineering area has to review such topics as matrix algebra and advanced mathematical analysis. This math barrier can be a major obstacle to engineers who hope to translate some of their practical manufacturing experience into effective numerical control computer programs.

COORDINATION, COMMUNICATION

Many establishments that became involved early in numerical control have taken a long, hard look at their part programing practices related to writing instructions for machine operators. This involved analyzing the quantity and nature of data required to set up and operate numerically controlled machines. In many cases this led to abbreviating the operations sheets or manuscripts (after defining what the operator really has to know), and expanding written setup instructions to prevent operator misinterpretation. Adequate downward communication became necessary to assure that the parts were oriented and located exactly as part programers intended. This became crucial as relatively few installations had their part programers present on the machine floor when tapes were proved out. On the other hand, assurance against a communication gap between the machine floor and the engineering department had to be provided, so engineering personnel could benefit from manufacturing experience—remedy defects and improve future performance.

As employers continued to expand their installations, it became more necessary for them to redefine the relationships—and standards for attaining them—of their numerical control personnel. When the first machines were installed, it was common practice to work out problems jointly; the machines were new, and both part programers and operators usually were inexperienced (though trained) in numerical control.

But as more equipment goes on line, more formal coordination is necessary. It is no longer feasible for a part programer to observe operators during the setup and operation of the first piece-part of a run, and answer questions and resolve operating difficulties. For the part programer, such free-wheeling liaison is psychologically satisfying but not economically justifiable. It is an expensive way to buy feedback, and becomes less satisfactory as the numerical control installation grows larger.

This emphasis on coordination and improvement in lines of communication is extending through all of numerical control manufacturing. The designers must have adequate understanding of numerical control potentialities—and limitations—to prevent a loss in manufacturing efficiency. So the team concept which is common in defense industries is being applied elsewhere. Part programers as well as production planners are being drawn into conferences in the preliminary stages of designing. This has an additional advantage. When these manufacturing engineering personnel participate in studies related to production feasibility, they will have fewer difficulties in visualizing the product and in developing proc-

esses and methods to make its manufacture possible. The chance for manufacturing error also is reduced.

For these reasons, an increasing number of plants have set up the position of COORDINATOR FOR NUMERICAL CONTROL. As is typical of newly emerging occupations, his job duties, responsibilities, and authority vary widely, as does his company title. He may occupy a staff position in the organizational structure and function in a purely advisory capacity; or he may have line responsibility and supervise a unit such as the part programing department, and perform coordinator duties as an additional responsibility. He may be a supervisory engineer, and be head of process and methods or all of industrial and manufacturing engineering. Whatever, he has one set of responsibilities that are crucial to the effectiveness of the numerical control effort; he must be an effective pipeline for giving and receiving information. He is the nerve center for numerical control communications, both upward and downward.

When something goes wrong in the shop—or could be improved—it is the coordinator's responsibility to get this information to the right hands in the right place. His contacts thus are with personnel in design and manufacturing engineering (including part programing). Other contacts are with tool design, accounting, quality control, purchasing, training and other personnel officers. Thus tact and something akin to salesmanship are essential. If not selling numerical control, at least he is the key person in promoting its effective use. He may also do some outside selling, to load the machines fully during slack manufacturing periods. He also may be instrumental in resolving manufacturing problems that originate outside the organization. One such major current problem is within-the-lot size and hardness variation in raw workpieces. The numerical control coordinator may have to convince management to set closer receiving requirements, despite greater purchase costs, in order to save even more money later through reduced manufacturing costs.

Liaison with the maintenance department and specialists such as quality control engineers to develop maintenance methods, also is a significant responsibility of a coordinator. Machine breakdowns are expensive—much more so than downtime on conventional machines. Also, the hidden costs of downtime are larger. Not only is extensive rescheduling necessary in many cases, but parts scheduled for numerical control may have to be pulled, and production replanned for manufacturing by conventional processes. If, in fact, that is possible. Sometimes it is not.

MANUAL PARTS PROGRAMING, OFFICE STANDARDS

Many employers are revising their procedures and methods to reduce the chance of producing faulty manual (non-computer) part programs. One change is toward requiring that part programers cross-check the work of other part programers, rather than check their own work for accuracy, because there is often a tendency to make the same mistake in verifying data that was made when recording it. In the course of a single day, a manual part programer may record 5,000 or more letters and digits of machine instructions on his special forms. All of these have a specific meaning, and an error can injure a machine operator, prevent processing, destroy a workpiece, or damage the machine tool. So what appears to be a trend toward cross-checking can be expected to continue.

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A well organized library of part programs, set up with the needs of part programers in mind and at a location convenient to them, can raise the level of programing accuracy—and productivity—dramatically. For example, once a certain bolt hole pattern is identified, it can be duplicated in whole or part from a previous part program. But only if the part programer can find it! Thus more emphasis currently is being placed on adequate cross-indexing of part programs, by nature of problems and their solutions. As manufacturers get more of their product mix on tape, the emphasis on adequate organization of part program libraries can be expected to increase.

Cross-checking techniques have also been applied in the clerical area, though apparently to a lesser extent. The reason for their application is much the same: human error, though here particularly in clerical perception, can cause havoc on the machine floor if the error is not detected and corrected. Numerically controlled machines are mindless. They will do only what they are instructed to do by the machine control tape. Thus the data typist (who prepares the tape by copying from the part programer's process manuscript) can introduce an error that results in a faulty machine instruction. The machine will try to follow its instruction, even if there is six inches of solid fixture or workpiece in the way. So in some installations, after the data typist checks her hard-copy (printed) output against the process manuscript, she routes them to another office clerk who does the same thing; then they are returned to manufacturing engineering, where a part programer checks everything again.

In plants where verifier attachments have been installed on data typewriters, the business practice of having typists verify each others' work (as has been the case in key punch departments for many years) is becoming common.

Of all companies that were surveyed during this project, none had errors on as much as one percent of their tapes as first released. However, scarred machine tables, and fixtures with drill holes in inappropriate places, gave evidence that the desired zero-error level of manufacturing planning is yet to be achieved.

It is perhaps strange that relatively large manufacturing concerns seem to have less trouble adapting to numerical control than small plants. But size and formal organization usually go together. Many years ago, most medium to large size manufacturers installed effective, formalized office systems, methods and procedures. These merely required modification when numerical control machines were delivered. On the other hand, many smaller shops never had set up formal office practices—and in fact avoided them. These shops are finding that freewheeling ways of doing internal business no longer are adequate, because of the breadth and detail of manufacturing planning required by numerical control.

TOOL DESIGN

Although the traditional work tasks of tool designers employed in short-run manufacturing appear relatively unchanged by numerical control, there are a number of worker factors and job duties that are receiving a different amount of emphasis.

First, the "ability to see the big picture." This statement is frequently heard, but seldom defined. Yet it is particularly significant in the case of

tool designers working in the numerical control area. Design of fixtures for universality—so they can be used in the machining of similar parts in the future—is receiving more and more attention. To do a competent job, the tool designer frequently has to learn more about the total scope of components manufactured by his employer, and understand the tooling implications of changing trends in the mix of manufactured products. Bad guesses can be very expensive.

Two- and three-way "turnover" fixtures, that simplify secondary setups on a machine tool, are being seen more frequently on bed- and table-type machines. More demanding of the tool designer's analytical talents, they are often the only way to fully utilize a machine's chipmaking potential. More complex and expensive than one-way fixtures (and often less rigid), their design requires meticulous attention to detail, and an enhanced knowledge of the dynamic processes of machining.

Fixture analysis and design are occupying an increasing amount of the tool designer's worktime. The need for design of jigs, especially drill jigs, is being reduced in almost direct proportion to the extent numerical control is adopted as a short-run manufacturing method: and need for design of custom cutting tools also is declining, with industry currently placing heavy emphasis on standardized tooling.

For these reasons, and because of the introduction of more sophisticated business systems for manufacturing planning and cost control, many tool designers are becoming tool selectors. However, such selection involves comparative analysis of machining feasibility, and much closer coordination and communication with manufacturing and design engineering personnel. Application of the tool designer's total abilities is more, rather than less, frequent.

Probably most tool designers have the education, training, experience and aptitudes to become competent part programers. A number of employers surveyed in this study reported they found that a background in tool design—whether academic, acquired on the job, or both—appears to be the ideal one for part programing. So industrial trends toward tooling standardization and universality may have beneficial effects on persons currently employed in, or considering entry into, the field of tool design.

A new promotional channel already has opened to jobs in part programing. Even if total industry demand for tool designers should decline, which seems doubtful, tool designers and workers in related fields of mechanical technology are naturals for selection as trainee part programers. Job opportunities in part programing almost certainly will continue to increase over the near term. The number of numerical control machines on order at the present time is large, and some machine tool manufacturers state that their plants are working at full capacity to meet current orders.

TOOL PRESETTING

Presetting is the selection and combination of tools, tool-holders and extensions (and frequently, coding rings or keys for automatic-tool-changing machines), before the tools are to be used. It also involves setting the tooling to specified lengths and diameters, working from sketches and written or oral instructions. Total presetting is not new;

it has been a common shop practice, particularly for turret-type and automatic machines. What is different with numerical control presetting is that it is more often done off the machine, and in many cases not even in the machining area.

What has been a group of work tasks for setup men and machine setup-operators, has now emerged as a job, separate from jobs on the machine floor and from the traditional tool room jobs. Some employers, however, have merely shifted responsibility of tool presetting to personnel experienced in operating tool grinders. In the high-precision sector of machining industries, experienced machine shop inspectors also have been an important source of workers for tool presetting. This may be because they were already familiar with precision gaging, optical, and even optical-electronic measuring instruments. Many tool presetting instruments are merely retrofits, modifications of precision measuring instruments to adapt them to new applications. Thus the additional training for inspectors is minimized.

The trend toward tool presetting is strong, although slowed somewhat because additional investment is required in tooling inventory. However, this cost is compensated for by an increase in manufacturing efficiencies, an increase that sometimes can be dramatic. Some employers are even presetting tools for the simpler 2-axis numerical control machines, on which tape control of the third (spindle) axis is not possible. They have found this to be economically justifiable for some, if not all, of their operations.

Preset tooling is implicit in the numerically controlled machining center concept of manufacturing. These machining centers—essentially, both general purpose and multiple-function machine tools—formerly were found primarily in aircraft, aerospace, and ordnance plants. It was here that their manufacturing efficiency was demonstrated, and they are now on order by manufacturers in many industries. As their proportion to conventional machines increases, the demand for personnel trained, or trainable, in the techniques of tool presetting can be expected to increase rapidly.

PROGRAM, TOOLING, AND TAPE TESTING

Dry runs are tryouts of unproven tapes on the machine to detect errors before the first piece of a run is machined. These are becoming less common as procedures and methods are introduced to detect errors before release of tape to the machine floor. On a dry run, the operator checks the performance of the machine—without a cutting tool in the spindle—against process sheet information and data from visual display indicators on the console, in order to detect gross errors. As an alternative to this air cutting, he uses a stylus in the spindle as a tracer, to prove out the tape on plastic or paper sheets.

Both of these methods are expensive. The machine is cutting air instead of metal, so the potential productivity of both worker and machine is reduced.

There is another method of proving out the part program and its tooling and tape. It is used primarily in plants that use multi-axis numerical systems to machine close-tolerance, complex workshapes. In these plants it

is often economically justifiable to machine and then fully inspect a piece of rigid, expanded-foam plastic before starting on the first actual piece. This is because the raw material cost for each piece—even quite small ones when exotic alloys or metals with heat-resistance are involved—may run from several hundred to many thousands of dollars.

JOB EVALUATION AND THE NUMERICAL CONTROL MACHINE OPERATOR

Workable programs of formal job evaluation and wage administration in the area of numerical control operations have proved very difficult to set up. One reason has been the tendency of employers to develop job evaluation systems based on machine functions, rather than job requirements. This is understandable because early steps usually are tentative, with machines often acquired one or two at a time. Also, numerically controlled machine tools commonly are erected, at least initially, in general machining areas, with the location often determined by the function and size of conventional machines they replace or augment. As a result, some fundamental differences in job requirements tend to be overlooked or understated.

Physical effort requirements changed markedly with numerical control. Machine positioning in at least two axes of movement becomes a tape rather than manual function. But setup and takedown are more frequent because of high machine productivity, and as manufacturing planning for numerical control becomes more experienced, the operator can find it increasingly difficult to stay ahead of the machine.

Apparently the most difficult conventional job evaluation factor to apply to numerical control is that of responsibility. Many of the duties and tasks previously assigned to the operator of a conventional machine tool—and his shop supervisor—have been transferred to the engineering department. Details of operator duties, and their sequence, are specified for him on operator manuscripts. Other functions of conventional machine operators now are a series of coded machine instructions. They are on the tape. But where does the final responsibility lie? Is the operator to be held accountable for workpiece quality, and will he be expected to notice machining problems, and either override feeds and speeds or notify his supervisor? Who is to be responsible for adequate tool life—the operator, the foreman, or the engineering department? In all cases, the operator is expected to remain alert, and try to shut down the machine in time to prevent major damage, when there is a control malfunction or part programing error. But is he required to anticipate problems such as those arising from variations in raw workpiece size, and trim his controls to prevent machining difficulties?

As yet, there are no absolute answers to many of the administrative difficulties presented by numerical control. Patching conventional job evaluation and wage systems to adjust to numerical control has not proved adequate, and an increasing number of employers are now setting up entirely separate classification structures and standards for numerically controlled machine operating jobs. Numerical control already has considerably changed hiring standards. Just a few years ago, no personnel officer would have recommended selection of entry machine shop workers on the basis of factors such as good high school English grades and the new math. But the binary languages and the paperwork aspects

of numerically controlled machine operating jobs now have made such selection factors fairly common. Numerical control is a new breed of cat, and to a certain extent so are its operators. Man-machine relationships are fundamentally changed.

Numerical control also has forced changes in functional organization, as major users begin to view it as an entirely new manufacturing system, and not just as strange looking, expensive and somewhat frightening pieces of hardware. Just as numerical machining has changed the content and interrelationships of jobs in manufacturing, it may compel fundamental improvement in design and operation of company wage systems. Questions—and major issues—are being raised both by management and labor, and current techniques of job evaluation and wage administration may not be good enough to provide the answers.

THE MACHINING CENTER

These numerically controlled machines are very versatile. Often, they can do all machining from start to finish on a piece. Center drilling, tapping, reaming, precision boring, counterboring and countersinking, and light (and sometimes even heavy-duty) milling all are possible. For this reason the machining center—actually a new concept of manufacturing—has no single counterpart among conventional machine tools. Thus, many currently employed workers were selected as trainee machining center operators because they had experience as setup-operators of conventional radial drill presses. Normally, radial operators are exposed to a large variety of machining problems and frequently are accustomed to organizing their work for relatively short production runs. Other operators had extensive experience on conventional boring and milling machines.

However, a trend appears to be emerging—that of hiring entry workers and bringing them along on numerically controlled machines only, with well-experienced machine hands being transferred back to conventional machine tools. Frequently, the new operators' first machines are light-duty, relatively low cost tape drilling machines. On these machines they can build up experience in drilling, tapping and boring practices, and learn basic concepts of machine setup, before being transferred to the more versatile machining centers. They also learn to read tape, the binary-coded-decimal, 8-channel tapes that are rapidly becoming standard for positioning (point-to-point) machines. Some employers state they now look for entry workers with the new mathematics training, because it reduces training time of learning control concepts and tape reading. Some employers, possibly an increasing number, place little emphasis on in-school shop training and relatively more on the academic curriculum. This, including mathematics through trigonometry, mechanical drawing, and English, is regarded as evidence that the job applicant possesses adequate aptitudes for numerical-control machining, and as an indicator of adaptability to changing work requirements.

There is another reason for emphasis on formal education when selecting operators. Part programing for positioning-control machines is a rapidly expanding occupation, and the worker with the more extensive academic background often is more likely to be promotable to a job as a part programer, once he gains a sufficient amount of practical machining experience.

SHOP SUPERVISION

Relatively few employers contacted during this study had made major changes in the work responsibilities of their machine shop foremen. Most of their foremen had had previous work experience as setup-operators of conventional machine tools, and were already working as foremen when the first numerically controlled machines were installed in their machine areas. Thus they were able to gain a general orientation during installation, debugging, and setting of shop standards for these machines. Relatively few of these men had actual experience in the operation of a numerically controlled machine, and even fewer had training or experience in part programing.

This situation has led to problems, however. These problems are especially acute during night-shift operations. Higher level supervisory staff, especially those in professional occupations, traditionally work on the day shift even when their manufacturing plant operates on a two- or three-shift basis. But, "Somebody here has to know part programing" is a common demand from the machine floor that is being met by management in several different ways. First, experienced part programers are being induced to accept work assignments on night shifts. Second, some shop foremen are being provided with numerical control training including part programing for specific machine-and-control systems, so they can assist in keeping machine downtime to a minimum. Third, selected numerical control operators are being trained in part programing and the techniques necessary to patch or salvage faulty tapes and part programs, and remedy unexpected difficulties. These workers are expected to develop potential for promotion into two areas where experienced workers currently are in critically short supply: numerical control shop supervision, and part programing. And if the trend toward numerical control continues as rapidly as at present, they may well become the key men of tomorrow's short-run manufacturing.

COMPARISON OF REQUIREMENTS BETWEEN NUMERICAL CONTROL AND CONVENTIONAL MACHINE OPERATIONS

With the introduction of numerical control—as with any new technology——there was a considerable lag before staffing requirements were fully appreciated. When the earliest machines were installed, it was a common practice to assign their operation to the best men, often journeymen machinists with many years of experience. One reason for this was machine justification. The first machines to be delivered were of the expensive and sophisticated contour-path milling type; it was felt only expert machinists with extensive experience on tracer-type machines could master their operation. This did not prove to be the case.

Few employers now assign fully qualified machinists to numerical control. Instead, much the same education, training and experience factors now are being applied as have been found useful to select setup operators of conventional machines in a job-shop environment. There are some differences, however.

Training:

Employers surveyed during this study tended to put considerable em-

phasis on formal, academic training when selecting operators for numerical control. This is partly because of the paperwork aspects of these jobs. Reading of operations manuscripts is an almost universal requirement. Another reason, frequently given, is that verbal ability is essential to prevent a communication gap. Operators should be able to recommend changes and improvements to the part programming department, based on their practical knowledge of machining. They must also be able to describe operating difficulties to maintenance personnel to keep expensive machine downtime to a minimum.

Less emphasis appears to be placed on specific vocational training when hiring numerical control operator trainees. Undoubtedly, a tight job market is a factor. However, a considerable number of employers said they would rather hire an entry worker with extensive high school mechanical drawing and mathematics background, no matter how much school shop-training he has had.

Experience:

Experience in the operation of conventional machine tools is no longer an absolute requirement. Increasingly, employers are assigning entry workers directly to numerically controlled machines. The line of progression is much the same as on conventional machines. Workers usually are first assigned to relatively simple, light-duty machines such as a single-spindle drill press. They then progress to larger, more complex machines. After two or more years, specialization in operation of milling-boring or turning machines is a common practice. The total of training time and experience to achieve average performance as an operator of a numerically controlled machine is commonly regarded as about one-half of that needed to operate a conventional machine tool. This is because of the many things that are on the tape or specified in detail on operations sheets, such as feedrates and speeds, that were and are responsibilities of the operator of conventional machines. For average performance as operator of a multi-purpose numerically controlled machine—the machining center that has no traditional counterpart and for which manufacturing planning is exhaustively detailed—one to two years frequently is regarded as sufficient. However, for the largest, most complex machines of this type, some employers insist on four or more years of shop experience because of high machine-and-control, tooling, and workpiece costs.

Aptitudes:

Verbal ability is required to comprehend operator manuscripts as well as the traditional paperwork packet (job and time tickets, etc.) accompanying each job order. An operator must possess the ability to describe events preceding a non-programed machine stop or machining error, to assist maintenance personnel in localizing and isolating mechanical, hydraulic and electrical-electronic malfunctions. He must be capable of describing errors in part programing and tape preparation to his supervisor. An operator should also be able to suggest modification of current, or changes in future tapes and thus improve feedback from the machine floor to the part programing department.

Numerical ability is required at the level of decimal addition and subtraction to interpret numerical displays, monitor machine performance.

and perform scratch-pad arithmetic calculations to inspect workpieces. Ability to learn non-decimal arithmetic is necessary[3] to acquire facility in identifying binary-coded-decimal machine commands on punched paper tape, and read binary display lights of controls if so equipped. This ability also is desirable to comprehend operating characteristics of electronic controls. Some employers regard successful previous completion of courses in the new math as a significant predictor of successful performance as a numerical control machine operator.

Spatial perception apparently is less essential for numerical control, with layout eliminated and other previous operator functions on the tape or specified on operator manuscripts. However, workers still must be able to visualize location or orientation of each workpiece, and its relation to fixturing and to cutting tools, from sketches and drawings that accompany his written instructions.

Clerical perception is needed to avoid perceptual errors in identification of alphabetic, numeric, and special symbols on operations manuscripts, and of visual machine-performance displays on the console. Operations manuscripts are not unique to numerical control, but are almost universally used in numerical machining. These manuscripts make clerical perception more important, because they detail, in writing, the nature and sequence of an operator's work tasks for each machining run.

Motor coordination and **finger** and **manual** dexterity are required to use inspection devices and handtools, adjust machine controls and maintain an adequate workpace during setup and takedown in order to hold expensive downtime of relatively new and potentially highly productive numerical control systems to a minimum. Replacement of traditional machine tool controls, such as handwheels and levers, by thumbwheel dials, decade switches and other electrical devices affects the relationship of the numerical control operator with the machining process, but does not eliminate the need for motor coordination, finger, and manual dexterity.

Interests:

Numerical control machine operators should have preference for working with machines and processes, to set up and monitor the performance of the machine tool and control system.

Operators should also have an interest in activities of a concrete and organized nature to perform work tasks in accordance with established procedures. The details and sequence of work tasks are outlined on operations sheets. In most cases, operations sheets describe exactly what tooling and fixturing to use, and how to locate and aline each workpiece. Machining feedrates and speeds frequently are specified in cases where they are not on the tape.

[3] Except in the relatively few installations where the operator has to restart the tape "from the top", or a manually marked restart point after nonprogramed stops, or has to get assistance from a supervisor. These practices make it unnecessary for operators to "read the tape", but only at the expense of considerable loss of productivity.

Temperaments:

The operator of a numerically controlled machine tool must use judgment based on training and experience to trim his controls in order to compensate for variations in workpiece hardness and size. He must make rapid—and correct—decisions in case of machine or control malfunction. The operator must also be alert for part programing errors, and inspect each machining cut with a micrometer, gage, or scale, when producing the first piece of a job run involving the use of a new, unproven control tape.

Physical Demands:

Strength is less important with numerical control than for operation of conventional machines. This is partly because of environmental planning to make most efficient use of new, expensive numerically controlled machines, rather than because of intrinsic differences between numerically controlled and conventional machine tools. However, differences in strength requirements among the various numerical control jobs probably will always exist because of the range of machine capacity and workpiece size.

There are however, several general statements that can be made about operator requirements, even though they may not apply to every plant that uses numerically controlled machines. Walking is reduced because more materials are brought to the operator—to increase his chipmaking time. Consequent lifting, carrying, pushing and pulling are reduced for the machining of each piece, again partly because of management planning. However, because of the increase of machine productivity, there often is more of all of these during a whole work shift. Use of power cranes and hoists is the usual practice, to reduce physical effort during machine setups. With numerical control, indexing tables under tape control, palletized setup and shuttle systems for automatic fixture and workpiece transfer are becoming much more commonplace; all of these tend to reduce the physical effort required by operators.

The need to make precise, coordinated control movements with arms, hands and fingers during machining operation is less frequent, because traditional controls such as handwheels are being reduced and even eliminated on numerically controlled machines. (To a lesser extent this is true even on conventional machine tools.)

Climbing and stooping and crouching are less significant physical demand factors. Table height is a tape-controlled function on some machines; thus the part programer can take setup convenience of the operator into account. Also, layout planning that precedes numerical control machine installation tends to reduce physical demands for operators as well as provide optimum conditions for the numerical control system.

Inspection, that can involve many awkward movements on the part of an operator just to get to the portion of a part to be inspected, is changed both in amount and nature. Reaching, handling, and fingering movements related to inspection by operators are reduced. Less inspection is required because of inherent machine accuracy and reliability. Also, the operator of a machine can observe position displays and program sequence number lights, and compare them to data on his operations

sheets to verify machine performance. This is a substitute for frequent use of inside, outside, and depth micrometers, and various types of gages used to check each metal-cutting step when using new, unproven machine control tapes and when spot checking subsequent parts.

The single most significant factor affecting physical demands is that many former operator functions now are on the tape. Two or more axes of cutting tool-workpiece movement are programed for numerical control. Thus, operator involvement with handwheels and levers typical of conventional machines has been reduced, and even eliminated on some machines. Many other functions, such as control of lubricant (coolant) flow, also can be incorporated into the numerical control system. Also, assuming that planning for tape preparation was adequate, there is less chance for an operator to produce a faulty part than in conventional machining operations. Extensive care is being taken to prevent tape errors by incorporating extensive checks and controls into part programing and tape-preparing procedures. This is the case both where manual (including tape-producing data typewriter) methods of tape preparation are used, and where computer-oriented systems are applied. Thus panic button stops, and need for modification of predetermined machine movements, feedrates and speeds by machine operators, are becoming less frequent. All of these further tend to lessen the physical involvement of operators with the machining process.

Talking becomes more significant—though not necessarily more frequent—as a physical (and mental) requirement.[2] Operators must be able to describe events preceding machine errors and non-programed stopages. Operators also should be able to explain why, in their opinion, such errors or stops occurred.

Hearing is helpful, though not critical, for numerical control as well as conventional machine operating. An operator alert to tool chatter and squeal can take remedial action to prevent tool breakage and workpiece damage. Hearing is also significant in learning the job, and in giving and receiving instructions at any later time.

Seeing requirements are relatively unchanged. Frequently, normal-range and near acuity are necessary: to read operations sheets or process manuscripts; interpret drawings and sketches; identify surface finish quality; use and read inspection devices; read tape; and set switches and dials, and monitor lights and visual numerical displays on control panels and consoles.

The need for far visual acuity when operating very large machines is being reduced by use of centralized control panels, periscope-type remote viewers, and closed-circuit television systems.

Visual accommodation—the ability to adjust the lens of the eye to bring objects at varying distances into sharp focus—appears to be more im-

[2] Talking and hearing are examples of physical demands that can be rendered less important or unnecessary by "job engineering." Modification of conventional communication methods, as by scratch-pad use to give and receive information, has long permitted use of totally deaf persons with or without speech, as machine tool operators. However, such reengineering is most suitably applied when adjusting the requirements of a single position to the abilities and limitations of one individual. It does not necessarily affect the worker requirements for the (broader-scope) job within the organization.

portant for numerical control than conventional machine operating. Part of the reason is the physical difference of the numerically controlled machine. It has additional controls and displays not found on its conventional counterpart. These often are installed in a cabinet that is separate from the machine. Therefore, there is a less tangible, less direct relationship of operator to workpiece. The operator shifts his attention frequently, and sometimes rapidly, from the workpiece/cutting tool interface to visual displays of actual machine performance on a console or control panel. Another reason for accommodation is that virtually all operators perform other secondary operations, such as manual deburring and inspection of previously-machined workpieces while their machine runs on the tape. Even where an operator has responsibility for only one machine, it is becoming common practice for him to organize as much of the next job as possible while tape-controlled machining is taking place, in order to hold change-over time to the minimum. Accommodation is especially necessary for the workers who operate more than one machine tool; they have to monitor the performance of a machine that is operating under full tape control, while setting up and operating another conventional or numerically controlled machine.

Working Conditions:

Most employers acquire initial experience in numerical control by replacing conventional with numerically controlled machines on a one-for-one basis. Or, one numerically controlled machine—a tape drill press, for example—may replace several conventional machine tools. In either case, the environmental conditions for the operator are approximately the same as before.

As employers acquire more numerically controlled machines, and gain extensive experience in their use, many of them prefer to establish a separate numerical control machining department. There are several reasons for this, including improved management control of machining operations. But a major reason many employers give is that they realize this is the only way to take full advantage of the inherent accuracy and repeatability of numerical control machining. Its potential often is compromised when there has to be a mix of numerical control and conventional machines in the tool room, or on the production floor. In manufacturing establishments that have taken the step of setting up one or several numerical control machining departments, the operators' environmental conditions usually are significantly improved. Manufacturing planning precedes such a conversion, and this includes both analysis of numerical control machine capabilities and definition of the organization's present and anticipated manufacturing requirements. Thus, it is no longer possible for a numerically controlled machine to be placed between a drop hammer and an annealing furnace, or in an otherwise unsuitable location. Cleaner, less dusty working conditions are usual. Machines are located where large fluctuations in temperature are unlikely. Vibration, induced by other machine tools and material-handling equipment, comes under intensive scrutiny. The physical plant and equipment also tend to be newer.

In some cases, "white room," laboratory-type environments are specified for numerically controlled machines. Here, the working conditions are close to ideal. Dust filtration, and temperature and humidity control are the rule rather than exception, in order to achieve extremely precise

machining accuracies. Similar environmental conditions exist in remote-control numerical control installations. These involve operator control by closed circuit television, from a console removed from the machining area. These installations are rare, thus far. They provide the only feasible means of machining such things as solid-fuel rocket propellants, and radioactive materials. In the latter case particularly, machining is performed under carefully prescribed conditions.

The hazards of operating numerically controlled machines are relatively unchanged from those of the conventional machines.

There is always the possibility of eye injury and minor cuts and burns from flying chips while metal-cutting is taking place. But the chipmaking time of numerically controlled machining may range from 70 to 80 percent or more; on conventional machine tools used in short-run machining, the actual productive time is usually 20 to 40 or 50 percent, and can be even less than this. Thus, the amount of worktime the operator is exposed to machine-caused minor injuries is potentially much greater. This is especially so when he is operating two or more machines simultaneously, a not infrequent occurrence with numerical control. However, the operator is less directly, and less closely, related to the machining process, and this tends to be a compensating factor. With numerical control, he does not often have to observe machining progress at close range to make compensating adjustments—at least, once the tape has been proven.

Major injuries are always possible in the machine shop, but may be reduced by numerical control. Management planning which preceds installation of major items like numerically controlled machines tends to assure adequate environmental conditions for the operator as well as the machine and control system. This planning also includes assuring adequate tooling and fixturing; thus, the need for operator improvisation —sometimes dangerous—is reduced. Also, part programing involves much more detailed production planning than is customary in traditional machining. The preplanning and specification of somewhat conservative machine feeds and speeds tend to reduce injuries caused by cutting tool breakage, particularly when relatively inexperienced workers are used as machine operators.

Wearing of reinforced-toe shoes and safety glasses has become a standard practice, and tends to reduce the frequency and severity of injuries to workers in numerical control as well as conventional machine operating jobs.

ELECTRONICS MAINTENANCE FOR NUMERICAL CONTROL

The trend toward solid-state components, as exemplified by the transistor, is currently having an effect on workers in this occupational area. It will also have an effect on future work force entrants. Employers state that, as compared to repairmen of vacuum-tube type numerical control systems, the solid-state control systems repair technicians need to have more knowledge of electronic theory. They also have to use more complex test equipment, such as dual-trace, laboratory quality oscilloscopes. Another requirement is more reference to technical manuals and the ability to interpret graphic and tabular materials such as waveform descriptors and voltmeter value charts.

Some manufacturers are making a concerted effort to simplify the servicing problem (defining the problem, then localizing it, and finally locating and then repairing or replacing faulty modules and components). One approach is by supplying diagnostic system-test and trouble-localization test tapes, along with handbooks describing their use. Also, circuitry now is being designed with repairing and servicing in mind. Plug-ins for test jacks are being located on a single plane on the console. Trouble indicator lights wired into control system test circuitry also tend to speed up as well as simplify his work.

Electronics modularization and miniaturization are having important effects on the numerical control maintenance function. Because of modularization, a module can be pulled and immediately replaced by another from inventory. The operator can get back to chipmaking while the repairman pinpoints trouble in the module at a more convenient place, and in a physically more comfortable manner. He does it at his own workbench—where he may now have on hand a set of newly marketed, plug-in type testers for semi-standardization modules. Or he may just mail the printed-circuit boards back to the manufacturer for repair and replacement. The result of miniaturization is the further lessening of physical work requirements of the job. But more emphasis is placed on analytical ability, because the companion of miniaturization is combination of functions, multi-purpose modularity, that makes troubleshooting more difficult, and repair perhaps impossible, or uneconomic in some cases, even with specialized equipment for component isolation testing and module repair.

THE OCCUPATIONAL DESCRIPTIONS

The occupations described in this booklet are those most directly concerned with numerically controlled metal-cutting machining. Since, however, occupations are still fluid, hiring requirements and qualifications for employment have not yet been fully standardized, and a certain amount of overlap will be noted among the occupational descriptions. Nevertheless, the occupational data assembled from many different sources, are a reflection of the existing situation. They must be regarded as composites of jobs, and cannot be expected to coincide exactly with any job in a specific organization. It will be necessary, therefore, to adapt descriptions to fit individual jobs before they can be used with complete accuracy. For this reason it is also important that the user of this material be familiar with the purpose and meaning of the various sections included in this brochure, and the several parts of the individual occupational descriptions.

For a full understanding of the descriptions and their relationships, both among themselves and with changes that have taken place and are likely to continue, it is necessary that the reader take into consideration some of the sections of the preceding narrative information. These are sections such as "Shop Supervision" and "Comparison of Requirements between Numerical Control and Conventional Machine Operations." This information is included there partly to avoid repetition among the descriptions themselves.

The job descriptions are arranged in alphabetical order by titles. The wording of the title that appears at the head of each description is a reflection of common usage. Other titles, or alternate titles, by which the same job is known also appear at the head of each description in small type. Between the main and alternate titles appears the occupational code which identifies the job within the classification structure of the third edition of the *Dictionary of Occupational Titles:*
The narrative portion of each job description is arranged as follows:

OCCUPATIONAL DEFINITION

A brief description of the duties involved in a particular occupation. It provides an understanding of the tasks that are performed, and the skills and knowledges necessary for the performance of those tasks.

EDUCATION, TRAINING, AND EXPERIENCE

An indication of the education and the level of training and experience usually required by management for employment in the occupation. As previously mentioned, considerable variation exists among employers as to required education, training, and experience. However, an attempt was made to indicate the complete range of such hiring requirements.

WORKER TRAITS

Provides some estimate of the worker trait requirements of the occupation. It has long been believed that the ability of an individual to adjust to a specific type of work situation is as significant as the education and training qualifications he brings to the occupation. Consequently, judgments have been made in terms of a number of components consisting

of aptitudes, interests, temperaments, physical activities and environmental conditions to which individual workers have to adjust. A listing and definition of each factor for the various components is contained in the Worker Traits section, beginning on page 68.

Aptitudes:

These are the specific capacities or abilities required of an individual in order to learn or perform some task. This component is made up of 11 specific aptitude factors. They include the nine factors contained in the General Aptitude Test Battery developed by the GATB. Those aptitudes were selected which seemed significant in the occupation and are identified in terms of specific work situations. The factor of intelligence, however, was not rated because of the difficulty in writing meaningful descriptive statements for this relationship.

Interests:

This component is defined as a preference for a particular type of work experience. It consists of five pairs of bipolar factors, arranged so that a preference for one factor in a pair generally indicates a lack of interests in the other factor in the pair. Those factors were selected which seemed to be significant to the job in question, and are identified in terms of specific situations.

Temperaments:

The temperaments component consists of 12 factors that reflect different work situations. Each work situation describes a type of activity that demands a different adjustment on the part of individual workers. Those temperament factors were selected that appeared to be significant in the occupation, and are identified in terms of specific duties.

Physical Demands and Working Conditions:

These reflect working conditions which make specific demands upon a worker's physical capacities. There are six physical activities factors and seven environmental conditions factors. Those factors were selected that were significant in the occupation in the sense that they met established criteria for successful performance.

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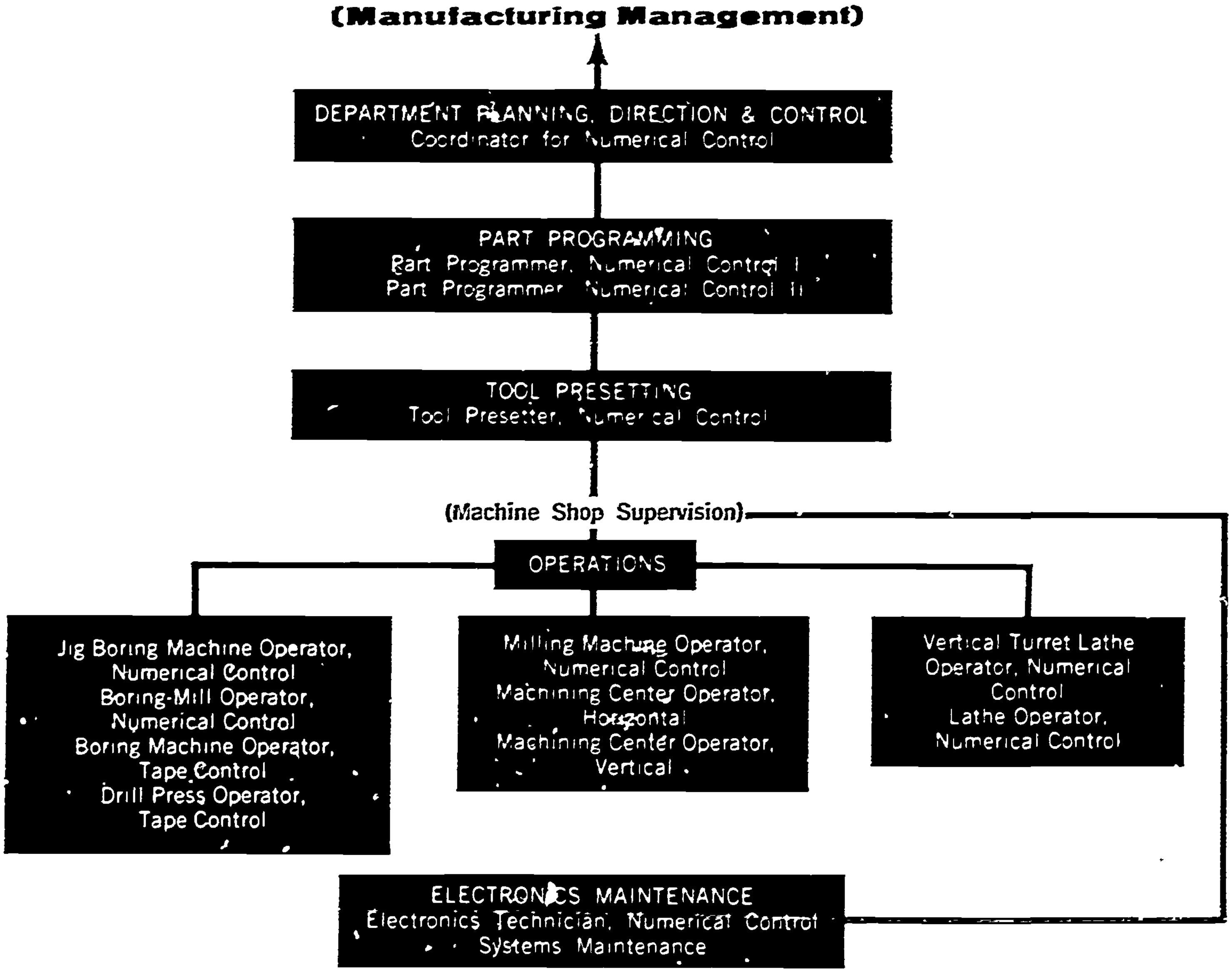
FUNCTIONAL ORGANIZATION CHART-NUMERICAL CONTROL INSTALLATION

(Manufacturing Management)



THE DESCRIPTIONS FOR:

BORING-MILL OPERATOR, NUMERICAL CONTROL

609.280

boring bar operator, numerical control; boring machine operator, numerical control; horizontal boring mill operator, numerical control; tape bar operator, numerical control

OCCUPATIONAL DEFINITION

Sets up and operates horizontal-spindle boring machine with two or more axes under preprogramed numerical control to bore, drill and mill metal work-pieces by applying knowledge of machining practices and metal-working procedures: Reads process sheets and studies blueprints and sketches to organize materials for each run and interpret setup and operating requirements. Signals crane operator, or operates jib crane and hoist, to locate and aline fixtures and parts. Levels workpiece with shims, and tightens in place with wrenches. Loads toolholder in spindle, and inserts edge finder (wiggler) or dial indicator in toolholder. Depresses switches to jog edge finder or indicator into contact with specif. point on workpiece, and turns indicator dials on control panel, to establish tool-and-workpiece relationship. Retracts spindle to remove setup gage and load first cutting tool. Sets conventional micrometer-type dials, cams, and stops as indicated on process sheets, if machine spindle axis is not tape-controlled. Places tape reel or loop in control cabinet and threads starting point of tape through read-head. Depresses switches to select mode of operation, advance tape, and initiate machining operations. Compares numerical displays of machining progress on control panel with data on process sheets to verify machine operations. Removes tooling, and installs next specified tool at end of machining cycle, or when worn.

and restarts machine. Occasionally verifies machining accuracy by using scales, gages and micrometers to compare workpiece specifications with those indicated on process sheets and blueprints. Trims dimensional control switches or installs undersize cutting tool when preliminary cut is necessary to prevent tool, workpiece and machine damage. Readjusts controls or removes and replaces cutter with size originally specified, and backs up tape and restarts machine at point of deviation from tape. Overrides and keeps record of deviation from programed feedrates and speeds when machining problems are encountered, or shuts down machine, explains problem and requests override authorization from supervisor. Readjusts tooling in machine, or in bench tool setting gages, before initiating close-tolerance finishing cuts.

Gathers and assembles tools, holders, and extensions for next job during tape-controlled machining cycles, and presets radial and longitudinal dimensions of tooling on bench gage as specified on tool layup sketches and process sheet instructions, to reduce idle time of machine. Sets up next part on machine during automatic-machining cycles when machine is equipped with twin tables or pallet-and-shuttle transfer system, or off machine when bench mounting of workpieces to standardized fixturing is specified in process sheet for next job and part and fixtures are to be loaded on machine as a single unit. Notifies supervisory or part programing personnel of unanticipated machining difficulties and their causes, and of any deviations that were necessary from the part program and tape as supplied in the job packet. Occasionally operates machine in dial-in or manual mode, when dimensional data on tape is inadequate for milling because of excess-material problems, or if tape has not been made or additional operations are specified on the process sheets that are not on the standard-part tape. Operates machine tool exclusively as boring-and-drilling machine, if control system is not capable of milling, or if management has prohibited use of machine on milling in order to minimize spindle wear and retain high machine accuracies.

May improvise fixturing from standard locating clamps and blocks, or from adjustable vises and chucks, by applying knowledge of machining practices, and studying process sheets and part sketch or blueprint to insure tooling clearances. May operate machine on dry runs, with machine unloaded or with stylus in machine spindle, to detect gross errors on unproven tapes. May set up and operate machine equipped with two or more spindles which permit simultaneous machining of identical workpieces. May machine non-metallic workpieces.

EDUCATION, TRAINING, AND EXPERIENCE

High school or vocational school graduation increasingly required of entry workers, with courses in machine shop, mechanical drafting or blue-print reading, and shop mathematics. Two to two and one-half years of background experience as setup-operator of machine tools on short-run work is regarded by many employers as sufficient if it has been oriented toward drilling, boring, and milling rather than metal turning. Other employers prefer to assign journeymen or those of equivalent experience, to some extent because of the high initial cost of large capacity heavy-duty machines.

However, production runs usually are very short. This is especially the case on two-axis machines: these frequently are selected for one-of-a-

kind. and matching-part machining. In most plants. operators of numerically controlled horizontals are required to machine a large variety of materials. Workpieces also range from complex castings and weldments, to "boiler plate sandwiches." Thus there is considerable justification for assigning only well-experienced operators to these machines. However, a continuation of present trend, toward separating the tool presetting responsibility from the operator. and toward imposing higher quality control standards on raw workpieces. may significantly reduce experience requirements in the near future.

From two to four months typically is required before the worker achieves adequate proficiency on one make and type of numerically controlled horizontal boring machine and control system after starting as an understudy to an experienced setup-operator. This time can be reduced about one-half. if he has had previous operating experience on another type of numerically controlled machine. or has taken numerical control orientation courses.

WORKER TRAITS

Aptitudes:

Verbal ability to interpret data displays on control panels and read written setup and operating instructions: and to describe machining difficulties. and events leading to machine malfunctions and breakdowns.

Numerical ability at level of decimal computations to verify machine performance against process sheet data. and use gages and micrometers. Binary arithmetic usually required. to read tape to select nearest restart point after shutdowns: however. this can be learned on the job and many operators keep the appropriate tape-interpretation chart in their work area. Mathematical requirements through trigonometry occasionally imposed: however. this is usually done only where extensive non-tape machining is expected. or if method and process engineering and inspection procedures have not been modified to take full advantage of the new machine's potential.

Spatial ability to interpret drawings and sketches of complex parts. on which multiple machining operations usually are required.

Clerical perception to perceive pertinent detail in written setup and operating instructions. and recognize alphabetic. numeric. and special symbols.

Motor coordination and manual dexterity to precisely aline and secure workpieces and fixturing. adjust tooling. and make rapid corrective adjustments of control switches in response to visual indications of metalcutting malfunctions.

Interests:

An interest in working with machines. processes. and techniques to set up. operate. and monitor tape-controlled performance of a machine tool.

A preference for activities of a concrete and organized nature to set up and operate machine according to specific. detailed. and sequential instructions.

Temperaments:

Must adjust to a variety of tasks requiring frequent change to monitor machine tool during automatic cycles while performing secondary operations that hold downtime to a minimum.

Must adjust to deciding what immediate corrective action to take in cases of machine control malfunction, faulty part programing or workpiece variation that precludes use of a standard-part tape.

Physical Demands and Working Conditions:

Work is medium, involving infrequent stooping or bending, and occasional climbing of steps or short ladder during setup and monitoring of machining processes. Uses jib crane or hoist, or obtains help from others, in loading and positioning of heavy tooling. Manual lifting and handling of objects such as large handtools and tooling usually is restricted to about 25 pounds. Physical requirements for worker tasks such as reaching and handling subsequent to setups typically are reduced, when numerically controlled machines are compared to conventional machine tools, because of reduction or elimination of involvement with handwheels and levers, and more frequent centralization of control panels and work station, with use of periscope-type remote viewers and even closed-circuit television monitors.

Near visual acuity and accommodation to follow process sheets, directly monitor machine performance, and observe optical data displays.

Work is performed inside.

COORDINATOR FOR NUMERICAL CONTROL

012.168

numerical control machining coordinator; numerical control coordinator

OCCUPATIONAL DEFINITION

Coordinates equipment acquisition, production planning, part programing, tooling, production and maintenance activities of personnel associated with numerically controlled machine tools, by applying knowledge of manufacturing engineering, machine shop methods, and training in numerical control applications: Confers with design and drafting personnel to acquaint them with requirements, develop standards and procedures, and resolve questions of design intent and manufacturing feasibility. Reviews recommendations of methods engineering personnel, or analyzes blueprints and specifications of workpieces to recommend selection of those most suitable for numerically controlled machining. Trains, or directs training of part programing and machine operating personnel. Advises tooling personnel in techniques of fixture and tooling design and selection, to develop and apply tooling of minimum cost and maximum universality. Analyzes equipment and nature of employer's

product mix, to recommend most suitable machine and control acquisitions, modification, and replacements to management, and assist management in long-range planning for numerical control utilization. Develops or reviews written records of part programing, operating and maintenance, to define company standards and policies, improve scheduling and cost control, and establish preventive maintenance program that makes most productive use of workers, machines and controls.

Recommends assignment and promotion of personnel, and advises management on outside training of most value to personnel. May solicit sale of engineering and part programing services, and of open numerical control time to outside firms in order to load machines fully. May supervise part programing, or process engineering and part programing departments. May assist management in setting wage and salary standards, and in resolving labor disputes.

EDUCATION, TRAINING, AND EXPERIENCE

Two to four years of formal post high school training in engineering or industrial management, or equivalent experience, is a typical minimum requirement. Many workers in this area, however, have had many years of experience in practical machining methods (as machinists, then tool designers or method and process engineers) and more limited academic education; they have supplemented this experience with extensive self-study and correspondence work. Part programing experience of one to two years—or more—is another common requirement, depending on distribution of job duties, complexity of the employer's manufactured product mix, and on sophistication of equipment in use. Five or more years of diversified background in manufacturing engineering is regarded as especially desirable, because problems that arise in the normal course of work are varied, as are the means of effecting their solution.

WORKER TRAITS

Aptitudes:

Verbal ability to translate engineering and shop nomenclature into terms understandable to nontechnicians, to read technical papers and manuals to keep up with rapid changes in machining, and to organize and present oral and written reports.

Numerical ability at level of algebra and elementary statistics to interpret or prepare production records and reports; at minimum level of shop trigonometry when teaching writing of, or preparing part programs; at levels of basic probability and distribution theory when assisting in developing preventive maintenance, statistical quality control and other management programs.

Spatial ability to read blueprints and drawings.

Clerical perception to detect and avoid errors in reading and preparing tabular records and reports.

Interests:

An interest in technical subjects to cope with wide range of problems involved in short-run machining and keep informed of new equipment and techniques. A preference for communicating with

people to instruct, answer questions and promote new machining concepts.

Temperaments:

Must adjust to planning and controlling work activities in (and outside) the unit for which he is responsible, by applying knowledge of engineering, machining and maintenance practices, and operations analysis.

Must have satisfactory working relationships with people in management, engineering, drafting and tooling, and with manufacturers' representatives, foremen, shop workers and customers.

Must adjust to making decisions and recommendations regarding functional reorganizations to facilitate processes, equipment purchases, and personnel selection and training requirements.

Physical Demands and Working Conditions:

Work is sedentary which includes occasional walking and standing.

Talking and hearing required in conferences and during exchanges of information about such topics as desirability of machining by numerical control, and manufacturing processing and maintenance problems.

Work is performed inside.

DRILL PRESS OPERATOR, TAPE CONTROL

606.382

drilling-and-boring machine operator, numerical control; numerical control drilling machine operator; tape drilling machine operator

OCCUPATIONAL DEFINITION[1]

Sets up and operates automatic-tool changing, turret-type, or single-spindle drill press that is numerically controlled in two or three axes of movement, to drill, ream, tap, and bore metallic and nonmetallic workpieces: Studies detailed, written instructions and part sketch on process sheets to understand setup and operating requirements, and select specified tools and workpiece holders such as blocks, risers and clamps. Loads one or several workpieces, and fixturing, in location and orientation specified on process sheets, and secures with wrenches. Sets depth stops, cams and switches on machine head as indicated on operations sheets, if

[1] Many manufacturers have marketed numerically controlled drilling and boring-machines with the added capability of light-duty milling (often as an option available at additional cost). These machines often are referred to as drill presses, or drilling and boring machines. However, operator requirements are different, because a limited amount of prior training or experience, or additional on-the-job learning time is necessary for the operator to gain a general familiarity with milling cutters and their application. For this reason, operators of these machines have been classified under MACHINING CENTER OPERATOR, VERTICAL.

machine spindle axis is not tape-controlled or if preset tooling is not used. Loads and secures tooling in machine spindle, tool magazine, or turret head. Sets switches and dials on numerical control panels according to process sheet instructions. Threads beginning point of tape into read-head of cabinet of console, and depresses switches to bring table or head to start point and initiate machining cycles. Turns switch to select block-stop mode when using unproven tape, and verifies conformances to tolerances by comparing numerical displays with process sheet and blueprint data, and by making measurements with scales, gages, and micrometers. Readjusts tooling in machine or tool setting gages, and trims controls before initiating finish cuts. Repositions workpieces during programed machine stops when secondary setups are specified.

Removes and replaces workpiece at end of machining cycles. Turns selector switch to full-automatic position, to permit machining each remaining workpiece of production run without operator intervention. Monitors automatic operation to detect errors, remove chip accumulation, readjust coolant flow, and recognize and replace worn or damaged tooling. Shuts down machine in event of machine error or malfunction, and notifies supervisor. Deburrs and spot-checks machined parts during tape-controlled machining cycles, to reduce machine downtimes. Occasionally operates machine in semi-automatic mode by setting selector switch and manually dialing in data according to oral or written instructions, to machine relatively simple pieces for which a tape has not been prepared, or to make changes in a standard-part tape. May shift machine zeros by following process sheet instructions, and turning and depressing switches, to repeat taped machining patterns in different locations. May operate two or more machines simultaneously when using proven tapes. May be designated according to name of manufacturer or trademark of machine tool operated.

BORING MACHINE OPERATOR, TAPE CONTROL

layout drill operator, numerical control; precision boring-and-drilling machine operator, numerical control; vertical boring machine operator, numerical control.

Performs essentially the same duties as DRILL PRESS OPERATOR, TAPE CONTROL except that the addition of a precision boring spindle to what is basically a drilling machine permits a high degree of machining accuracy and repeatability. To achieve near-jig-bore machine capabilities, establishes setup points with proving bar, precision dial indicators and set-up blocks. Occasionally improvises holding fixtures from standard blocks and clamps. May be permitted to override programed feedrates and speeds.

EDUCATION, TRAINING, AND EXPERIENCE

High school or vocational school graduation increasingly required of entry workers, with some training in shop mathematics and metal-cutting practices. When these workers are not available, many employers prefer to select workers with a background such as mechanized farming, or extensive shop-related hobby experience, that gives some indication of possible job success. Workforce entrants with extensive courses in mathematics and mechanical drawing, but without any training or ex-

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perience in machine operating, often are hired and immediately assigned to numerically controlled machines as "understudies" or "learners." However, many employers prefer to assign these workers to operation of conventional single-spindle drill presses for a minimum of three to six months and then transfer them to relatively light-duty numerically controlled machines. This practice gives the new worker confidence as well as machine shop experience and thus tends to allay "buck fever" when he is introduced to the machine.

The employer usually provides up to one month of on-job training under decreasing amounts of supervision to workers assigned to these machines. Length of time required to achieve adequate performance can range from a few months to one year because tolerance requirements, raw materials mix, and production run lengths vary so widely. A general orientation course in numerical control concepts can reduce training time somewhat, but can not be considered a substitute for firm grounding in shop practices and metal-cutting procedures.

A significant difference between numerical control and conventional machine operating is that the numerical control operator usually is not allowed to sharpen his own cutting tools, though he may touch them up. Good tool geometry is critical to numerical control machining because jigs are not used. The effect of this standard is to reduce training time slightly.

WORKER TRAITS

Aptitudes:

Verbal ability to comprehend process sheet instructions, explain operating difficulties, and describe events preceding machine errors or breakdowns.

Numerical ability at level of decimal computations to verify machine performance, interpret numerical data displays and use gages and micrometers. (Training in non-decimal number systems is helpful in learning to read tape but is not a job prerequisite.)

Spatial ability to interpret setup sketches and properly set up fixturing and workpieces.

Clerical perception to avoid perceptual errors, and recognize alphabetic, numeric, and special symbols.

Motor coordination and manual dexterity to set up fixturing and workpieces, adjust tooling, and rapidly move switches and controls to stop machine or correct errors.

Interests:

An interest in working with machines and processes to set up, operate, and monitor numerical machine-and-control system.

Interest in activities of concrete and organized nature to operate machine according to specific and detailed instructions.

Temperaments:

Must adjust to a variety of work tasks subject to frequent change, demanding rapid transfer of attention between monitoring of

machine and performance of auxiliary tasks during tape-controlled machining cycles. Operators need to be alert for possible damage. and must prevent unnecessary machine downtime.

Must have disposition to meet standards and requirements specified on operating sheets. written instructions. sketches. etc.

Physical Demands and Working Conditions:

Work is medium. Manually lifts and loads tooling. fixutres and workpieces seldom exceeding 20 pounds to avoid time-consuming use of cranes and hoists.

Stands, and walks frequently within machine area, when setting up, unloading, and monitoring performance of machine.

Near visual acuity and accommodation to follow process sheets, monitor tape-controlled metal-cutting, and analyze displays of data on cabinet or console for indications of error.

Work is performed inside.

ELECTRONICS TECHNICIAN, NUMERICAL CONTROL SYSTEMS MAINTENANCE

828.281

maintenance man. electronic; numerical control maintenance specialist: numerical control technician

OCCUPATIONAL DEFINITION

Repairs contour path. straight-cut and positioning-type electronic numerical controls of machine tools, following manufacturers' manuals: Discusses events immediately preceding machine error or stoppage with machine operator and machine maintenance personnel to eliminate the possibilities of operator or part program error and machine failure. and to determine the general nature of the malfunctions. Localizes. isolates, and repairs or replaces faulty modules and components by following schematics, diagrams and handbook instructions. using such aids as a dual-trace oscilloscope. test probes. and electrician's handtools. to restore control system to operating condition. Tests system by using system and trouble-localization test tape to simplify diagnostic tasks, whenever such tape is available. Inserts replacements for defective modules when control is of modular design. and repairs defects later, at workbench. or returns modules to manufacturer for replacement.

Follows preventive maintenance schedules to reduce breakdowns and machine errors by such means as replacing components before they become defective or marginally functional. Keeps written records of downtime and nature of malfunctions to provide statistical base for modifying these maintenance schedules. Repairs associated machine tool electrical and electromechanical components. or guides shop electrical maintenance personnel who performs this function. Maintains spare parts inventory.

May repair machine tool hydraulic and mechanical defects. depending on breadth of training and experience. May also repair electronic control systems that monitor and control continuous-flow industrial processes and machines other than machine tools. May originate testing procedures.

May devise and construct module-test equipment. May assist on installation, checkout, and maintenance of numerical controls at customers' establishments as manufacturer's representative.

EDUCATION, TRAINING, AND EXPERIENCE

High school graduate. Graduation from a two year post high school technical school with an electronics major is a frequent minimum requirement, and is becoming more common as more of these schools offer a major, or option, in electronics. Military training and experience in repair of complex, specialized military electronic systems is especially desirable, because these courses normally:

1. expose the trainee to orientation in both general and special-purpose systems.
2. train attendees in non-decimal number systems,
3. provide a background in servomechanism theory as applied to any control system from all-electronic down to mechanical, and
4. introduce the concepts of calculus, essential to understanding how many control systems operate—although calculus is not normally necessary in their repair.

Thus, military systems training and experience can dramatically reduce the length of on-the-job experience required (after specialized training) to be proficient in the repair and maintenance of numerical controls for machine tools.

Customer training supplied by manufacturers of machine tool numerical controls is intensive in nature and usually ranges from one week for maintenance of a simple positioning control system, to two to three weeks for a complex, contour control system, and in almost every case presumes extensive previous training in the basics of electronic as well as electrical theory. For electronics, these basics include AC and DC circuit theory, amplitude and phase modulation, transistor and vacuum tube operation, and training or experience in the use of test equipment, especially oscilloscopes. Some employers follow up numerical control maintenance training by arranging for their employee to work along with an experienced man in the manufacturer's or some other plant—a combination of training and experience—for up to two months before their first numerically controlled machine is installed.

Many employees selected for numerical control training have been shop electricians with a background of studies and hobbies involving electronics, rather than extensive academic training.

An increasing number of users are supplanting the manufacturers' numerical control courses with in-plant training by their own personnel. This approach has two distinct values. Training can be oriented toward the users' operations, and geared to the aptitudes and backgrounds of their learning groups.

Training time may be reduced in the future as numerical control courses become integrated into academic curricula. Currently, a number of employers are demonstrating their community responsibility by making some employees available on a released-time basis, for part-time teaching duties in local vocational schools and colleges. This has considerable significance, because qualified instructors in electronics are scarce, and the shortage is expected to continue.

When employed by a control manufacturer, the worker usually receives six to twelve months' additional training and experience before being assigned to field service work, to become competent in all types of numerical controls the employer manufactures.

Test: U.S. Employment Service. Specific Aptitude Test Battery S-103

WORKER TRAITS

Aptitudes:

Verbal ability to discuss reasons for machine and control malfunctions and stoppages, read and assimilate technical materials, and suggest changes in standards and procedures that might reduce downtime.

Numerical ability to level of decimal and binary arithmetic and Boolean algebra (logic) to comprehend functions of numerical control switching circuitry, perform diagnostic tests, interpret display lights, read punched paper control tapes, and keep written downtime and inventory records. A course in introductory differential and integral calculus is very helpful in providing a background for understanding how complex machine-and-control systems operate, and successful completion is an indicator of fairly high numerical aptitude; however, such a course is not regarded as absolutely necessary for successful on-the-job performance.

Spatial ability to interpret waveform displays, and to comprehend schematics and diagrams and relate physical components to them.

Form perception to check circuitry for such defects as loose or corroded connectors, and for presence of dust or other foreign matter.

Clerical perception to perceive pertinent detail in written material, as when comparing test displays to handbook values.

Manual dexterity to use test probes and handtools.

Finger dexterity to move small objects in confined work spaces.

Color perception to recognize and work with color-coded components.

Interests:

An interest in working with machines and techniques for repairing them.

A preference for activities resulting in tangible satisfaction to repair, and perform preventive maintenance services on electronic control systems.

Temperaments:

Must adjust to a variety of tasks, such as initiating a series of tests to localize and diagnose equipment failure, and carrying out preventive maintenance duties.

Must be able to make decisions concerning performance of equipment based on factual information such as test data, manufacturers' manuals, and predetermined test routines, to isolate and identify marginal or faulty components.

Must adjust to working with precise and established standards of accuracy indicated by written specifications, and at speed sufficient to hold machine downtime and production rescheduling to a minimum.

Physical Demands and Working Conditions:

Work is light, involving lifting and carrying equipment seldom exceeding 10 pounds, occasional pushing and pulling of heavier, dolly-mounted test equipment, and infrequent stooping and crouching.

Reaching, handling, fingering, and feeling to work with delicate, miniaturized printed-circuit modules and components.

Near visual acuity and accommodation to read handbooks, schematics, diagrams and tabular data, to operate precision test instruments, and repair complex, miniaturized equipment. Color vision to distinguish among colored wires and interpret color codes.

Work is performed inside.

JIG BORING MACHINE OPERATOR, NUMERICAL CONTROL

606.280

horizontal jig boring machine operator, numerical control;
vertical jig boring machine operator, numerical control

OCCUPATIONAL DEFINITION

Sets up and operates vertical or horizontal-spindle numerically controlled jig boring machine to perform such functions as center drilling for layout, drilling and rough boring, and finish boring, countersinking, counterboring and inspecting, by applying knowledge of manufacturing properties of metals and machining methods: Studies operations manuscripts, blueprints, sketches, and tooling instructions to determine engineering intent, and processing sequence and methods. Loads fixtures and workpiece as specified on sketches or in narrative instructions, and secures in place by use of wrenches. Loads tape in read head of control. Jogs machine, with edge finder or precision dial indicator in spindle, into contact with part, or fixture or table blocks and gages. Depresses switch to set machine zero. Installs preset tools in specified sequence and jogs to zero point to initiate tape-controlled machining; sets conventional cams, stops, and dial-type switches on machine head as indicated on operations sheets if machine spindle axis is not under control of tape.

Inspects each cut on first piece of run to trim console controls and readjust cutting tools, in order to achieve desired concentricity, boring tolerances, spatial relationships, and surface-finish quality. Discusses operating difficulties with supervisory, engineering and maintenance personnel, and recommends improvements in future similar part programs, by applying extensive practical experience in machining. Presets cutting tools off machine during tape-controlled cycles by using precision presetting instruments, and organizes materials for next job, to reduce machine downtime. Frequently works close to or at very limit of machine

accuracies, which currently range from ± .0001 to .000050 inch. Occasionally operates machine tool as inspection machine, in manner similar to normal operations, by inserting precision measuring instruments in spindle, and moving machine through cycles under tape, dial-in, or manual control, to indicate deviations from prescribed tolerances.

May replace cutting tools with high speed grinding unit to improve surface finishes and hold closer tolerances when doing finishing work. May operate machine that has the added capability of milling, but which is classified as a jig boring machine rather than milling machine because of tolerance-holding potential. May operate jig-type machine in which boring head has been replaced by measuring head, solely as high-precision inspection instrument. May regrind cutting tools. May improvise workpiece-holding fixtures from standard blocks and clamps.

EDUCATION, TRAINING, AND EXPERIENCE

High school or vocational school graduate, or equivalent, usually with courses in machine shop practices, shop mathematics, and mechanical drawing. Employers frequently require two to four years of precision, job-run experience as a setup-operator of conventional high-precision machine tools, or journeyman machinist status; usually, this is followed by one to three months as learner or trainee to learn basic concepts of numerical control and become familiar with one make and type of machine and control system. Experience in interpreting complex finished-part blueprints, in use of ultra-precision measuring gages and instruments, and extensive knowledge of dynamic processes of machining are regarded as most significant; the time required by workers with such a background to master numerical control concepts usually is relatively insignificant.

WORKER TRAITS

Aptitudes:

Verbal ability to confer with supervisory, part programing and maintenence personnel about operating difficulties; and to interpret written setup and operating instructions.

Numerical ability at level of decimal and binary arithmetic to perform scratchpad arithmetic, interpret display lights, and comprehend meaning of coded tape perforations. Some employers require knowledge of shop trigonometry, to enhance manufacturing flexibility; trigonometry can be essential to operate machine occasionally in manual or dial-in mode, when tape and process sheet have not been prepared by engineering, or when minor changes are required in tape when using conventional blueprints.

Spatial ability to visualize setup practices, machining processes and finished workpiece from two-dimensional drawings and sketches.

Form perception to interpret surface finishes and recognize minute defects in workpieces, during machining process.

Clerical perception to perceive pertinent detail in written material, and in visually displayed data.

Motor coordination, and manual and finger dexterity to precisely align and secure workpieces and fixturing, and use precision inspection and tool-setting instruments.

Interests:

A preference for working with machines and processes to set up, operate, and monitor the performance of the machine-and-control system.

Interest in activities of a concrete and organized nature to follow well-defined instructions for the production of each part, or group of parts.

Temperaments:

Must adjust to a variety of tasks during each short-run machining cycle, to assure adequate standards of machining quality and speed, and hold expensive machine downtime to a minimum.

Must adjust to adhering exactly to established standards and procedures contained in operations manuscripts, blueprints, sketches, and tooling instructions.

Physical Demands and Working Conditions:

Work is light, involving frequent standing, and walking within machine area and occasional stooping or bending when setting up for, observing progress of, and inspecting accuracy of machining. Many employers require worker to obtain assistance when handling objects over 20 to 25 pounds, to reduce possibilities of personal injury and material damage.

Reaches, handles and fingers, to set up tooling, load and thread tape in machine control unit: set and make trimming adjustments on multi-position switches: and verify progress of machining with precision gages and measuring instruments, to very limit of machine-and-control accuracy.

Normal and near visual acuity, and occasional accommodation, to read manuscripts and drawings, observe machining processes, and observe display devices on machine, and on control console.

Work is performed inside.

LATHE OPERATOR, NUMERICAL CONTROL

604.382

automatic-tool-changing lathe operator, numerical control: engine lathe operator, numerical control; turret lathe operator, numerical control

OCCUPATIONAL DEFINITION

Sets up and operates numerically controlled horizontal lathe to turn, bore, face, thread and taper-turn metal workpieces: Reads process sheets and studies blueprints and sketches of part and tooling, to determine sequence and nature of work activities. Inserts beginning point of tape in reading head of control system. Manually loads, or uses hoist, and affixes work between centers, in a chuck, or to a face plate. Selects and

installs preset tooling in tool posts, turrets, or indexing heads and automatic-tool-change magazine, in sequence specified on process sheet. Depresses pushbuttons and toggles, and sets digital selector switches that augment or replace the handwheels and levers of conventional machine tools, to jog first tool to part set point, advance tape and start metal-cutting.

Observes numerical displays on control panel and compares with data on process sheets to verify dimensional adjustments, feedrates, and speeds of machining cuts. Compensates for such factors as tool spring and wear, and workpiece deflection, by applying practical knowledge of machining, and turns dials and switches to override tape control and correct machine performance. Explains operating difficulties to supervisory, maintenance, and process planning personnel, and notifies them of any deviations from part program. Trims controls and readjusts cutting tools prior to machining of finishing cuts. Inspects first piece of run and spot-checks succeeding pieces by using micrometers and precision dial gages to verify accuracies. Studies job packet and organizes materials for next run during automatic tape-controlled cycles, to shorten change-over time.

May preset tools before positioning them in lathe, using precision presetting gages and instruments. May set up and operate another machine tool during tape-controlled machining cycles when using proven tapes, or perform other work such as parts deburring. May machine nonmetallic workpieces.

EDUCATION, TRAINING, AND EXPERIENCE

High school or vocational school graduate preferred, with courses in machine trades.

Amount of on-the-job experience employers require on conventional lathes varies widely. Some employers indicates that six months to one year of work as a setup-operator of a conventional lathe on short production runs is sufficient to gain an understanding of most commonly-recurring metal turning problems, but other employers prefer to select numerical control lathe trainees from workers with two years or more of job-shop lathe experience. Workers usually are assigned to numerically controlled lathes as learners, and work under very close supervision for approximately one month. After this, workers frequently require six months to one year to achieve average production and workpiece quality standards.

Final responsibility for workpiece quality usually is the responsibility of the lathe operator, who must compensate for factors not foreseen by part programing personnel, and make control adjustments to maintain spatial relationships, hold tolerances and compensate for factors such as tool spring and workpiece deflection. The amount of operator decision making is greatest when part programing personnel lack adequate background in details of metal turning practices; currently, this is not uncommon because of the relative newness of numerically controlled lathes.

Lathe operators traditionally have regarded themselves as either engine lathe or turret lathe hands. However, some employers are finding that experience in either area is adequate as background for numerically controlled lathe work. Basic knowledge of metal-turning machining and tooling practices, particularly in relation to tool compensation, apparently

are becoming recognized as more significant than experience on a specific type of lathe.[1]

WORKER TRAITS

Aptitudes:

Verbal ability to interpret written setup and operating instructions, and explain operating problems and malfunctions to foreman, maintenance and part programing personnel.

Numerical ability at level of shop arithmetic to use inspection devices to interpret machining progress, make scratchpad computations, and set trimming devices on control console to hold specified tolerances. Numerical ability at level of non-decimal arithmetic to learn reading of punched control tape, comprehend control principles, and better explain problems of interpretation of machine-and-control malfunctions.

Spatial ability to interpret drawings and sketches of parts that often are complex, requiring multiple operations.

Clerical perception to perceive pertinent detail in written setup and operating instructions, and recognize alphabetic and numeric symbols.

Manual dexterity to use inspection devices and handtools.

Interests:

An interest in activities concerned with machines, processes, and techniques to operate one or more types of numerically controlled lathes.

Preference for activities of a concrete and organized nature to set up and operate machine according to specific, detailed and sequential instructions.

Temperaments:

Must adjust to a variety of tasks requiring frequent change, and division of attention between own work tasks and monitoring of machine performance, to permit maixmum productivity.

Must adjust to deciding to select immediate corrective action from a limited range of alternatives, when part program is faulty or if he encounters wide variation in size or hardness of raw workpieces.

Physical Demands and Working Conditions:

Strength requirement is medium, involving infrequent stooping, and occasional awkward reaching, when setting up and inspecting

[1] Setup and operation of the "automatics", bar and chucker-type automatic screw machines or lathes, still is an occupational specialization. Although certain functions such as feedrates, speeds and rapid traverse are on the tape when these machines are equipped with numerical control, the machines are basically the same as their conventional counterparts: the same worker requirements still exist to set tools for close tolerances and adjust trip blocks and pins for non-tape operations.

work. Manually lifts and installs lighter workpieces seldom exceeding 20 pounds. Worker actions related to setup, takedown, and tool setting and readjustment typically are more frequent than on conventional lathes, because of high metal-removal capacity, and high ratio of metal-cutting to non-productive time of new numerically controlled machines.

Near visual acuity and accommodation to follow written manuscripts, monitor machine performance, and shift attention to optical display and signal lights on machine control unit.

Work is performed inside.

MACHINE CENTER OPERATOR, VERTICAL

609.380

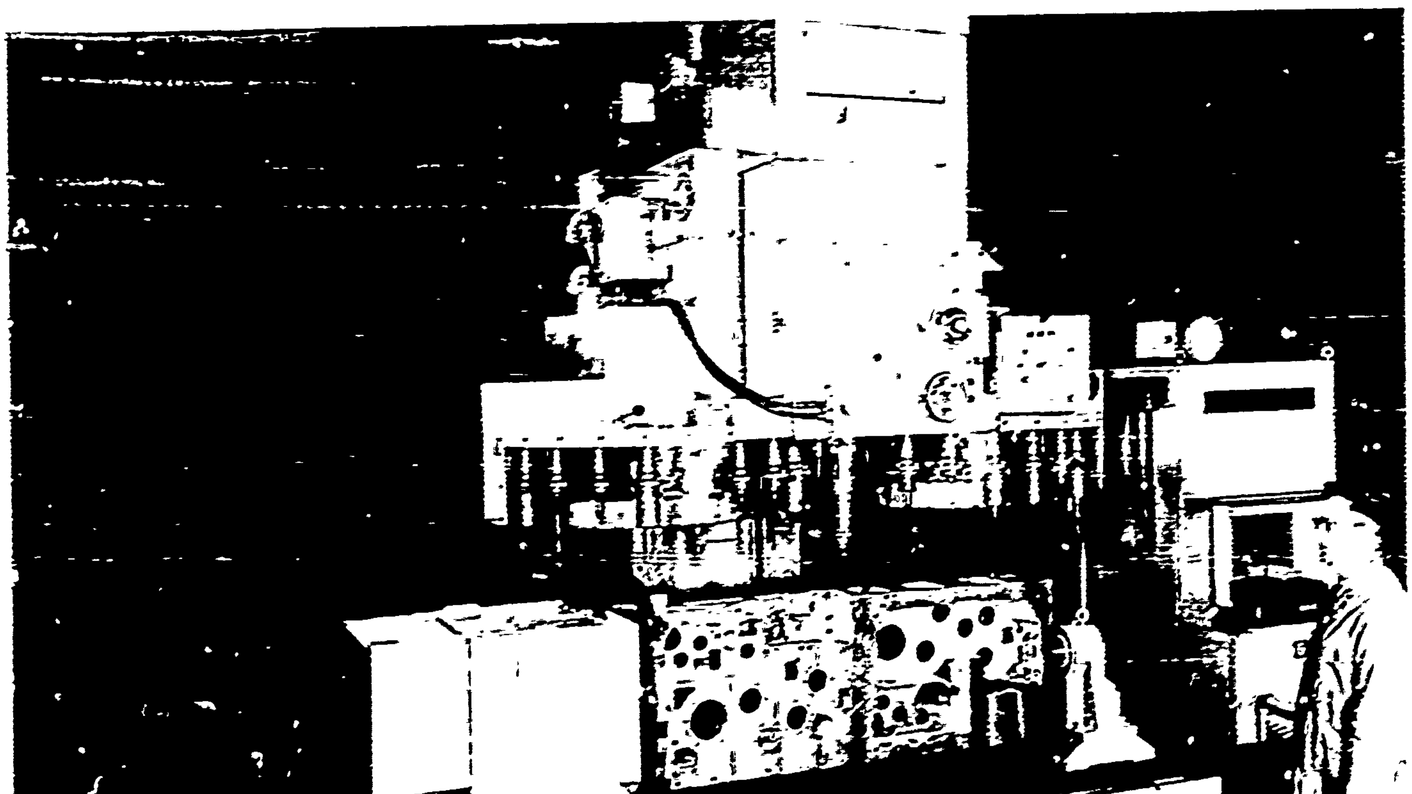
numerically controlled machining center operator, vertical; vertical drilling-boring-and-milling machine operator, numerical control

OCCUPATIONAL DEFINITION

Sets up and operates automatic-tool-changing, turret-type, or single-spindle vertical multi-purpose numerically controlled machine, to drill, ream, tap, bore and mill workpieces according to drawings, sketches, and

written instructions: Loads one or several workpieces, and fixtures, blocks or clamps, manually or by use of crane or hoist, in position and orientation specified on setup sketch and operation manuscript. Tightens bolts by use of wrenches, to prevent workpiece movement during machining. Installs and tightens preset tools in specified sequence. Loads tape into read-head of control cabinet of console. Sets depth stops, cams and dial-type switches on machine head as indicated on operations sheets, if machine spindle axis is not under control of tape. Brings machine head to specified start point by depressing job buttons and alining cutter visually or with use of feeler or dial gages. Turns and depresses switches to initiate machining. Tests unproven tape by operating machine in block-stop mode and inspecting each successive cut with scale, gage or micrometer. Compares measurements with data on blueprints, sketches and manuscript, to verify accuracy of part program. Repositions workpiece during programed machine stops when secondary setups are specified on operator's manuscript. Removes and replaces workpiece at end of machining cycles. Turns selector switch to permit machining subsequent parts of production run under full-automatic tape control without operator intervention. Monitors cutting action and positioning and sequence number display lights, to detect errors while machine is operating under full-automatic control.

May reset machine zeros on table by jogging machine head to new position with manual switches, and depressing reset button, in order to repeat



a taped machining pattern in another location. May be required to apply independent judgment and knowledge of metal-cutting practices. to override tape controlled machine movements. feeds and speeds. in order to compensate for variations in workpiece size and hardness. May preset. or readjust preset tooling off the machine to specified length and diameter. by use of precision presetting gages. Stops machine when operating difficulties or malfunctions occur. notifies supervisor. and explains problem. Deburrs and spot-checks machined parts while machine is operating under tape control. to reduce machine downtime. Occasionally operates machine in semi-automatic mode by setting selector switch and manually dialing in data from written or oral instructions. to make minor changes in a standard part and eliminate need for new tape. May operate two or more machines simultaneously when using proven tapes. May be designated according to name of manufacturer or trademark of machine tool operated.

MACHINING CENTER OPERATOR, HORIZONTAL

Performs essentially the same duties as MACHINING CENTER OPERATOR, VERTICAL, except that machine spindle or spindles are horizontal. numerical control of at least three axes of positioning is customary. control system is more likely to include profile-and-contour milling capabilities. and configuration and characteristics of machine often permit loading of larger workpieces and higher metal-removal rates than possible on the majority of vertical-spindle machines. Normally. all tooling is preset and all fixturing is specified in detail. Twin tables or pallet-shuttle transfer devices frequently are integrated into the machine-and-control system; where this is not the case. the operator sets up workpieces off the machine (on fixture plates) during automatic-machining cycles whenever feasible. to reduce changeover time. Horizontal machining centers almost universally incorporate automatic-tool-changing magazines and tool-transfer mechanisms, to take full advantage of inherent machine productivity.

EDUCATION, TRAINING, AND EXPERIENCE

High school or vocational school graduate preferred. with courses in machine tool operation and blueprint reading. Some employers express a preference for entrants with extensive high school background in mathematics—the new math—and mechanical drawing because they feel these are evidence of good mechanical aptitude as well as predictors of later job success. The ability to speak. read and write English is essential, to follow written instructions on the operations sheets for each job until he understands it thoroughly. and to explain operating difficulties.

Training varies widely, both in nature and amount of time devoted to it. Many employers prefer to let the trainee operator learn by doing. working as an understudy of another operator for one to four or more weeks. During this informal training, he acquires the ability to read tape. and learns machine and control functions. After this. he takes over as machine operator. though with assistance available when he needs it. For the first three to six months operating difficulties are likely to be frequent.

Other employers have set up formal training programs. Usually these start with numerical control orientation classes, then shift to group or

individual instruction on the machine and control system to be used. In the latter phase, training usually is organized around the operations manual that all manufacturers make available. Toward the end of his training, he may prepare one or several simple part programs. Not until then does he return to the shop for training through actually operating the machine. Formal training such as this is expensive and lengthly—one to three months is common—but has values that may not be readily apparent. The operator is likely to be more productive and make less scrap. He is better able to take remedial action when something goes wrong, and describe operating difficulties to part programing, maintenance and supervisory personnel. He tends to have more confidence in the part programer and thus is less likely to shut down his machine or trim his controls unnecessarily. Too, such training also is a means for discovering unexpected promotional potential of shop workers.

Six months to one year or more previous job-run industrial experience on conventional machine tools is a common requirement. Setup and operation of a radial drill press is regarded as particularly suitable, because normally operators of these machine are exposed to a variety of machining problems, on short run work. Sometimes, extensive experience—several years, or even journeymen machinist status—is required. Often, this is because an employer is just beginning to use numerical control, and feels this is the best way to justify the new, expensive machine. But industry is realizing that such workers, particularly if they are capable of organizing their work procedures for conventional machines, are likely to become bored and inattentive when operating numerically controlled machines. Thus, there is a danger in assigning an over-qualified worker—unless there is a mutual understanding that he will become a part programer and machine operating is only part of his training program.

As more and more machines are installed, employers are increasingly training entry workers in the operation of numerically controlled machine tools only, with no exposure to conventional machines. Where this is done, management usually assigns the worker first to its smallest machine (frequently a light-duty tape drill), and then transfers him to more complex, or at least more expensive, machines, on which he can continue to develop his work experience.

WORKER TRAITS

Aptitudes:

Verbal ability to understand written setup and operating instructions and to communicate with supervisor about machining problems; terminology on operations sheets frequently is abbreviated and highly conventionalized.

Numerical ability at level of decimal arithmetic to verify performance of machine-and-control system during machining of first piece of run when using unproved tapes, and to spot-inspect subsequent workpieces by using micrometers and gages. While not always a requirement, mathematics at level of binary arithmetic is very desirable to discuss operating problems, and to read tape in order to select valid points after non-programed machine stops and thus hold machine downtime to a minimum.

Spatial ability to visualize positioning and alinement of workpieces and fixturing from sketches and drawings.

Clerical perception to perceive pertinent detail in written setup

and operations-sheet instructions, and in visual-display data panels. Manual dexterity to use inspection devices and handtools.

Interests:

A preference for activities concerned with machines, processes and techniques to operate and monitor metal-cutting machining system.

Interest in activities of a concrete and organized nature to operate machine tool according to detailed, sequential instructions.

Temperaments:

Must adjust to a variety of tasks, and divide attention between own work tasks and monitoring of machine when in full-automatic operation, to make possible maximum operator and machine productivity.

Must adjust to adhering closely to established standards and procedures specified in written instructions, drawings, and sketches.

Physical Demands and Working Conditions:

Work is medium, involving continuous standing, and frequent walking within machine area. Manually lifts and positions lighter fixturing and workpieces, seldom exceeding 20 pounds, to avoid delays caused by use of jib crane or hoist. Workpace frequently must be rapid when using proven tapes to prevent non-programed machine shutdowns.

Reaches, handles and fingers to set up and take down work, adjust machine controls, direct flow of coolant, remove chip build-up with air hose, and verify machining accuracies by use of inspection devices or instruments.

Normal and near visual acuity, and occasional accommodation, to interpret data on drawings and operations sheets, monitor machining processes, and observe visual data-display devices of control system.

Work is performed inside.

MILLING MACHINE OPERATOR, NUMERICAL CONTROL

605.380

OCCUPATIONAL DEFINITION

Sets up and operates multi-axis numerically controlled milling machine by following written instructions, blueprints and setup sketches and applying knowledge of machining practices, to machine metallic and nonmetallic workpieces: Reads operator's manuscript and studies setup sketch, tool charts and part drawings to interpret detailed setup and operating specifications for each job. Signals crane operator or operates crane and hoist to locate and aline parts and fixturing. Levels workpiece with shims, and tightens in place with wrenches. Places perforated or magnetic tape in control console and threads through read-head. Sets machine and control dials and switches by following instructions on operations sheets. Inserts precision indicator in machine spindle, and

depresses switches to jog into contact with target point on workpiece or fixture, synchronize tape and tool, and record setup point. Retracts spindle, and loads and secures first preset tool and holder. Initiates tape-controlled machining and monitors metal-cutting performance. Compares numerical data displays with specifications on operations sheets, and uses scales, gages and micrometers during programed inspection stops, to verify machining operations. Removes and replaces tooling when worn or damaged, and when next tool is specified on manuscript.

Assembles and presets tooling at bench during tape-controlled machining cycles, by use of presetting gages, to reduce machine downtime. Readjusts tools or trims controls before initiating finish cuts, to compensate for factors such as workpiece variation and tool deflection. Overrides programed feedrates and speeds by applying knowledge of machining practices, or shuts down machine, explains problem and requests override authorization. Notifies supervisor and describes operating difficulties in all cases of obvious part program error, and machine or control malfunction. Repositions workpiece for intermediate setups when specified on operations sheets, and removes and replaces at end of machining cycles. Studies job packet and organizes materials for next job during tape-controlled machining cycles, to reduce changeover time. Occasionally replaces milling with drilling and boring tools at specified change points, to reduce or eliminate need for subsequent machining of workpiece on other machine tool. Occasionally operates machine in dial-in or manual mode to add or modify functions programed on standard-part tape.

May operate machine in test mode and inspect each machining cut when verifying unproven tape and program manuscript on first workpiece. May operate machine on preliminary dry run before machining first part, by visually observing for gross errors, or plotting two-dimensional movement with recording stylus. May test-machine first piece of rigid, expanded-foam plastic, or low-cost metal, when workpiece cost is high. May be designated according to make, trademark, or configuration of machine, characteristics of control system, or type of product, as Contour Path Tape-Mill Operator; Planer-Type Milling Machine Operator, Numerical Control; Profile Mill Operator, Tape Control; Tape Control Skin Mill Operator; Tape Control Spar Mill Operator; Tape Keller Operator; Variax Operator.

EDUCATION, TRAINING, AND EXPERIENCE

High school or vocational school graduation increasingly required of entry workers, with courses in machine shop, mechanical drafting or blueprint reading, and shop mathematics. Two to two and one-half years of progressive, short-run shop work, starting with drilling and boring, then specializing in milling operations, is regarded by many employers as adequate preliminary experience.

Other employers prefer to assign journeymen with extensive experience on conventional manual and/or duplicator-type milling machines. This is partly due to high costs of the machine-and-control system, and equipment downtime. However, use of these machines for jobs such as milling aircraft skin sections with integral stiffening structures from the solid, and for complex profile and contour milling that was formerly possible only in the tool room (when possible at all), tend to justify assignment of well-experienced operators.

It is possible that experience requirements may be relaxed as numerically controlled milling machines gain greater acceptance outside the aircraft, aerospace and ordnance industries. Trends toward better tape and process manuscript verification prior to release, tighter raw-workpiece quality control, and tool presetting by specialists are other factors that may reduce experience requirements for operators of numerically controlled milling machines.

One to three months or more are required before the worker achieves average proficiency on one make and type of milling machine and control system, after starting as an understudy to an experienced operator. If the worker has taken numerical control orientation courses and has operated another type of numerically controlled machine, training time can be reduced by approximately one-half. Six months to one year of additional experience may be required before the operator is permitted to machine a workpiece using an unproven control tape.

WORKER TRAITS

Aptitudes:

Verbal ability to comprehend written setup and operating instructions, describe operating difficulties and sequences of events preceding machine malfunctions and stoppages.

Numercial ability at level of decimal computations to verify machine performance, use micrometers and gages, and perform scratchpad computations. While not always a requirement, ability at level of binary mathematics is desirable to reduce tape-read problems and more rapidly comprehend functions of numerical control system during on-the-job training.

Spatial ability to visualize configuration of machined parts from drawings, and position and aline fixturing and workpieces from setup sketches and written instructions.

Clerical perception to perceive detail in manuscripts, charts, prints, sketches, and data displays.

Motor coordination and manual dexterity to use handtools, inspection instruments and tool setting gages, and make rapid corrective adjustments of switches on portable and fixed control panels in response to visual indications of machining discrepancies.

Interests:

An interest in activities concerned with machines, processes, and techniques to set up and monitor performance of tape-controlled machine tool. Preference for activities of a concrete and organized nature to operate machine according to well-defined sequential instructions.

Temperaments:

Must adjust to a variety of tasks, and divide attention between monitoring of machine performance and other work duties, to hold machine downtime to a minimum.

Must adjust to adhering to precise, established standards indicated by detailed written specifications, blueprints, and setup sketches.

Physical Demands and Working Conditions:

Work is medium. involving infrequent stooping or bending. and occasional climbing of steps or short ladder (on larger machine) during setup and monitoring of machining processes. Manually lifts and handles handtools and tooling. seldom exceeding 25 pounds: may use jib crane and hoist for lifting and positioning heavier objects. Portable control panels, and the provision of a centralized work station that frequently is equipped with remote viewers. tend to reduce physical requirements subsequent to workpiece setup.

Reaches, handles, and fingers to set up and take down work. adjust machine controls, redirect flow or spray of coolants, remove accumulations of chips. and verify machining accuracy with inspection devices and instruments.

Normal and near visual acuity. and occasional visual accommodation. to follow operations sheets. directly monitor machine performance. and observe visual data-display devices.

Work is performed inside.

PART PROGRAMER, NUMERICAL CONTROL I

007.187

continuous-path part programer; contour part programer. numerical control; contour-path part programer; programer, numerical control

OCCUPATIONAL DEFINITION

Writes part programs in computer-processable language to define setup. tooling and operation of continuous-path and multi-axis point-to-point numerically controlled machine tools such as profiling and die-sinking milling machines, by applying knowledge of mathematics, machining methods and practices, and familiarity with specialized part-programing languages: Studies drawings. sketches. and conventional or mathematical-analytical design data, to comprehend intent of designers, visualize workpiece, and define fixturing and processing requirements on machines with as many as five axes of motion of each spindle under coordinated numerical control. Writes series of symbolic and numeric statements that describe workpiece in form such as series of geometric regions and boundaries, and that define clearance planes, machining modes, tolerance limits, type, radius, coding, initial position, feedrate and direction of movement of cutting tools. and coolant use.

Develops tool path sketches to plan machining procedures and assure collision-free clearance planes for cutting tools. Uses desk calculator with square-root generator, or input-output terminal to remote computer, in order to simplify computational tasks. Prepares sketches and specifications for tooling, fixturing, and machine setup and operation. Routes part programs for computer processing and preparation of written printouts, plots, and magnetic or paper control tapes used to control machine tool. Compares computer printouts to original manuscript, and design data and drawings. to identify and correct part programing and processing errors before release for tooling and manufacturing. Reads trade literature to keep informed on improvements in equipment, and processing and manufacturing techniques.

May confer with design personnel, applying specialized knowledge of machining complex workshapes by numerical control, to determine product machinability, and suggest changes in design and drafting practices to reduce time and cost of part programing, computer processing, and numerical machining. May operate, or review output of automatic drafting and digitizing machines, to reduce computational efforts of part programing, or verify accuracy of workpiece profiles and paths of cutter center-lines. May observe test machining of first piece with unproven tape, to assure adequacy of part program. May develop or refine time and cost data as a by-product of part program, to eliminate duplication of effort by industrial engineering department.

May organize training materials and instruct in part programing and operation of numerically controlled machine tools. May prepare part programs for manual processing when process manuscript is short and relatively simple to prepare, or if numerical machine control is capable of circular or parabolic interpolation. May originate or modify computer programs and routines that simplify part programing. May be designated by employer according to type or group of machine tools for which preparing part programs, such as aircraft skin and spar milling machines, or by trademark of machine, control, or programing language for which part programs are prepared.

EDUCATION, TRAINING, AND EXPERIENCE

High school graduation, with advanced mathematical preparation and courses in mechanical drawing, is the usual minimum requirement. Many employers further require two years or more of post high school education in a technical school or engineering college. Experience of one to two years in areas of process planning and tool design for conventional machine tools is commonly required, because much training in part programing assumes this background, as well as knowledge of machine shop practices and metal-cutting procedures.

Intensive training courses in contour-path and multi-axis straight-cut and point-to-point part programing, oriented toward persons with the above background, rarely exceed two to three weeks in duration. These courses usually are directed toward one make or type of machine and control, or part programing language. Close supervision and guidance by experienced part programers for the next three months is usually necessary. One year of experience is required to achieve adequate productivity and versatility, and meet high standards of accuracy.

As with many relatively new occupations, employer requirements have varied widely. At first, higher mathematics seemed to be a "must." As employers gained experience with complex numerical machining, they assigned workers with mathematical training only through high school trigonometry to continuous-path part programing. This did not prove to be satisfactory, except where the size of the installation permitted job breakdown, with these workers being given only the simpler assignments while they continued their education in mathematics on a part-time basis. Now, however, selection factors are becoming more standardized. Mathematical preparation at the level of analytic geometry, vector analysis, and matrix algebra, is regarded as very desirable, if not necessary.

The increasing capabilities—and availability—of digital computers do not reduce the need for mathematical preparation. Computers, and the

increasingly English-like input language with which they are addressed, only relieve workers of much tedious, manual computation. Computer programs for part program processing are becoming increasingly flexible and powerful. These factors make advanced mathematics even more necessary than before, because the part programer more frequently can select from an array of alternatives in preparing mathematical-geometric descriptions of complex workpiece surfaces.

In installations where part programers perform additional duties of computer programing, such as modification of computer post processors to adapt to new machine tool capabilities, additional background requirements of an engineering and scientific programer normally are applied. These include training for workers to become familiar with at least one class or type of digital computer, and with one or more computer programing languages.

WORKER TRAITS

Aptitudes:

Verbal ability to learn specialized, symbolic part programing languages, discuss problems of interpretation and machinability with personnel in design and methods engineering, and prepare written instructions for workers in areas of tooling, fixturing, and machine setup and operation.

Numerical ability at level of trigonometry, analytic geometry and calculus to comprehend functions of numerical control system and prepare part programs. Mathematics at level of vector analysis required to select from alternative part programing methods, and achieve optimum balance of part programing, computer processing, and machining time.

Spatial ability to visualize workpiece from engineering drawings and define as series of geometric surfaces, plan machining sequences and avoid tool collisions, and procedure tooling, fixturing, and setup sketches.

Form perception to see pertinent details, and distinguish symbols on engineering mechanical drawings and sketches.

Clerical perception to identify numbers, letters and symbols, and learn and retain English-like words that may number in the hundreds for a single part programing language.

Interests:

A preference for activities that are technical in nature to use mathematics to convert design data and drawings into format that permits numerical machining.

Temperaments:

Must adjust to a variety of activities such as resolving questions of design intent, determining suitability and availability of standardized tooling and fixturing, analyzing alternative part programing methods and machining sequences, and reviewing computer output during the course of a single assignment.

Must adjust to making decisions on a judgmental basis when using past experience to select best part programing techniques

and sequence of machining cycles and thereby save time and cost of investigating alternative methods.

Must adjust to conforming to accepted standards in recording processing statements in specialized part programing language, in adhering to standardized nomenclature when preparing setup instructions for operators, and in complying with established machine feedrate and speed conventions.

Physical Demands and Working Conditions:

Work is sedentary, requiring occasional lifting and carrying of handbooks and manuals seldom exceeding five pounds.

Frequently handles pencils, reference tables, and code sheets to identify and record machine commands and other data on process manuscripts.

Near visual acuity and accommodation to analyze mechanical drawings and select and post alphabetical, numerical, or special symbols in correct sequence or location on work sheets.

Work is performed inside.

PART PROGRAMER, NUMERICAL CONTROL II

007.187

point-to-point and straight-cut part programer; process planner, numerical control; programer, numerical control

OCCUPATIONAL DEFINITION

Writes part programs defining setup, tooling, and nature and sequence of numerically controlled machine tool operations, to machine parts as specified on engineering drawings and sketches, by applying knowledge of machining practices and shop methods: Studies design data and drawings to determine intent of designer, and visualize workpiece configuration and setup location and orientation on machine tool. Designates base point for machining when not specified, by applying knowledge of numerical machining practices. Converts dimensional data on drawings to base point reference, by using mathematics at levels of arithmetic, geometry, and trigonometry, when conventional rather than cartesian-coordinate drafting practices are used by workpiece designers. Plans sequence and nature of machining procedures utilizing familiarity with capabilities and limitations of specific numerically controlled machine tool such as horizontal boring and milling machine or vertical turret lathe, and knowledge of shop practices and physical properties of materials. Writes detailed, sequential statement of machine commands and operator instructions, using specialized language, symbols and (usually) planning sheets, to specify location and orientation of workpiece and fixturing, and other factors such as tool path and dimensional tolerance data, feedrates and speeds, size and type of cutting tools, movements of machine table, and programed machine stops for inspection or tool changes. Uses desk calculator with square-root generator, or input-output terminal to remote computer, in order to simplify computational tasks. Develops tool path sketches to plan milling procedures and assure clearances when part is machined. Prepares tooling and fixturing sketches and specifications.

Defines information needs of operator, and prepares separate, abbreviated operator manuscript, when detailed process sheets are not used on machine floor.

Reviews completed process manuscripts prepared by self, or cross-checks those of others, to detect and correct errors. Routes process sheets to computer center or clerical pool, for preparation of computer-printed or typed copy, and paper or magnetic tape used to control machine tool. Reviews returned copy, and cross-verifies with original, in final effort to detect and correct part programing and processing errors before release to manufacturing group. Reads trade literature to keep informed on improvements in equipment, and processing and manufacturing techniques.

May observe machining of first part with unproven tape when numerical control installation is new and personnel relatively inexperienced, or when unusual machining problems are anticipated. May confer with design personnel, applying specialized knowledge of numerical control to determine product machinability, and suggest changes in design and drafting practices. May develop or refine time and cost data as by-product of part program, to eliminate duplication of effort by industrial engineering department. May organize training materials and instruct in part programing and operation of numerically controlled machine tools. May originate or modify computer programs and routines that simplify part programing. May specialize in part programing for single make, type, or group of related machine tools, or in specific part programing language and format, and be designated accordingly.

EDUCATION, TRAINING, AND EXPERIENCE

Minimum requirement usually is high school or vocational school graduation. Experience of one to two years, or more, as setup-operator of machine tools on short runs that expose worker to diversity of machining problems, is a frequent additional prerequisite. Some employers prefer to temporarily assign workers selected as part programers to positions as rate setters and routers for conventional machine tools for six months to one year, to gain added background in company standards, methods, and manufacturing problems. Graduates of two-year mechanical technology courses frequently are selected in preference to fully experienced operators or machinists, though sometimes this is because their academic training is more recent. A few employers who have had several years of experience in personnel selection for numerical control stated they regard successful completion of courses in tool design as the most effective predictor of probable success as a part programer. Formal, intensive classroom training in part programing for a single type of machine and control system rarely exceeds one to two weeks, but approximately one year of experience is required to achieve average productivity and meet stringent standards of accuracy.

Sometimes, workers without any machine shop or related background are selected on the basis of achievement in advanced mathematics (which is regarded as evidence of adequate aptitudes for part programing, such as spatial perception); almost invariably, these workers are assigned relatively simple part programing tasks for the least complex machine tools for three to six months or more. Where this technique of job breakdown is applied, the worker often has to spend about three months in the shop

[illegible] machine shop or elsewhere [illegible] a background in shop practices before receiving training in, and beginning work as a part programer.

In installations where part programers perform additional duties of computer programing, such as modification of computer post processors to adapt to new machine tool capabilities, additional background requirements of an engineering and scientific programer normally are applied. These include training for workers to become familiar with at least one class or type of digital computer, and with one or more computer programing languages.

WORKER TRAITS

Aptitudes:

Verbal ability to confer with engineering and operating personnel about difficulties in design interpretation, part programing and machining, and to write concise, unambiguous instructions for machine operator.

Numerical ability at level of shop arithmetic, geometry and trigonometry to write part programs; and non-decimal arithmetic and Boolean algebra to comprehend functions of numerical control system, and read perforated machine control tapes and binary machine display lights. Mathematics at level of analytic geometry can be necessary when product mix of organization includes sophisticated work shapes.

Spatial ability to visualize raw and finished part from engineering drawings and sketches, avoid tool collisions, envision detailed sequence of machining cycles that will produce part most efficiently, and produce tool lay-up and setup sketches.

Form perception to see pertinent details, and distinguish symbols on drawings and sketches.

Clerical perception to identify, record and verify numbers, letters, words and special symbols that make up machine commands of part programing language.

Interests:

A preference for activities of a technical nature to cope with wide range of processing problems, and keep abreast of rapid changes in techniques of part programing.

Temperaments:

Must adjust to situations requiring the making of decisions on a judgmental basis, using past experience and knowledge to select best sequence of machining cycles without timing out alternative methods, and incorporate portions of previously prepared part programs to reduce time and cost of preparing manuscripts.

Must adjust to situations requiring the making of decisions on a factual basis, as when assigning feedrates and speeds previously

found to provide optimum balance of such factors as accuracies and surface finishes, machining time, and tool life.

Physical Demands and Working Conditions:

Work is sedentary, requiring occasional lifting and carrying of handbooks and manuals seldom exceeding five pounds.

Frequently handles pencils, reference tables, and code sheets to identify, and record machine commands and other data on process manuscripts.

Near visual acuity and accommodation to analyze mechanical drawings and select and post alphabetical, numerical, or special symbols in correct sequence or location on work sheets.

Work is performed inside.

TOOL PRESETTER, NUMERICAL CONTROL

609.384

tool presetter; tool setup man, numerical control

OCCUPATIONAL DEFINITION

Assembles and presets cutting tools at location away from machining area prior to job runs, by following written instructions, charts, and tooling sketches, and using presetting blocks, gages and instruments, to reduce setup time of operators: Studies tooling sketches and scans process manuscripts or operator instructions to determine tooling requirements. Selects from inventory and manually assembles specified tools, tool-holders and adapters, extensions, and tool coding rings and spacers. Sets length and diameter of such tools as boring bars, within prescribed tolerances, by use of such devices as toolblocks with dial gages, and instruments such as comparator-type optical, and optical-electronic precision presetting machines. Inspects and substitutes other cutting tools for those that are worn or chipped. Manually stamps coding keys, used on some automatic-tool-changing machines to identify specific tools, by referring to manuscript and master tooling charts, and turning dials and depressing lever on manual key punching device. Attaches keys to preset tools. Arranges all tooling for each job, and places in tool cart or tote pan with accompanying packet of written data, and program tape, for routing to machine floor.

May use bench-mounted simulators that duplicate machine components such as turret heads, to simplify tool presetting and verify cutting tool clearances. May preset tools for conventional (non-numerical control) machine tools. May keep inventory and disbursement records, and prepare requisition forms. May operate grinding machine to sharpen metal-cutting tools.

EDUCATION, TRAINING, AND EXPERIENCE

Graduation from a high school or vocational school with courses in machine shop practices and procedures is the usual educational requirement when hiring entry workers. Some employers regard successful

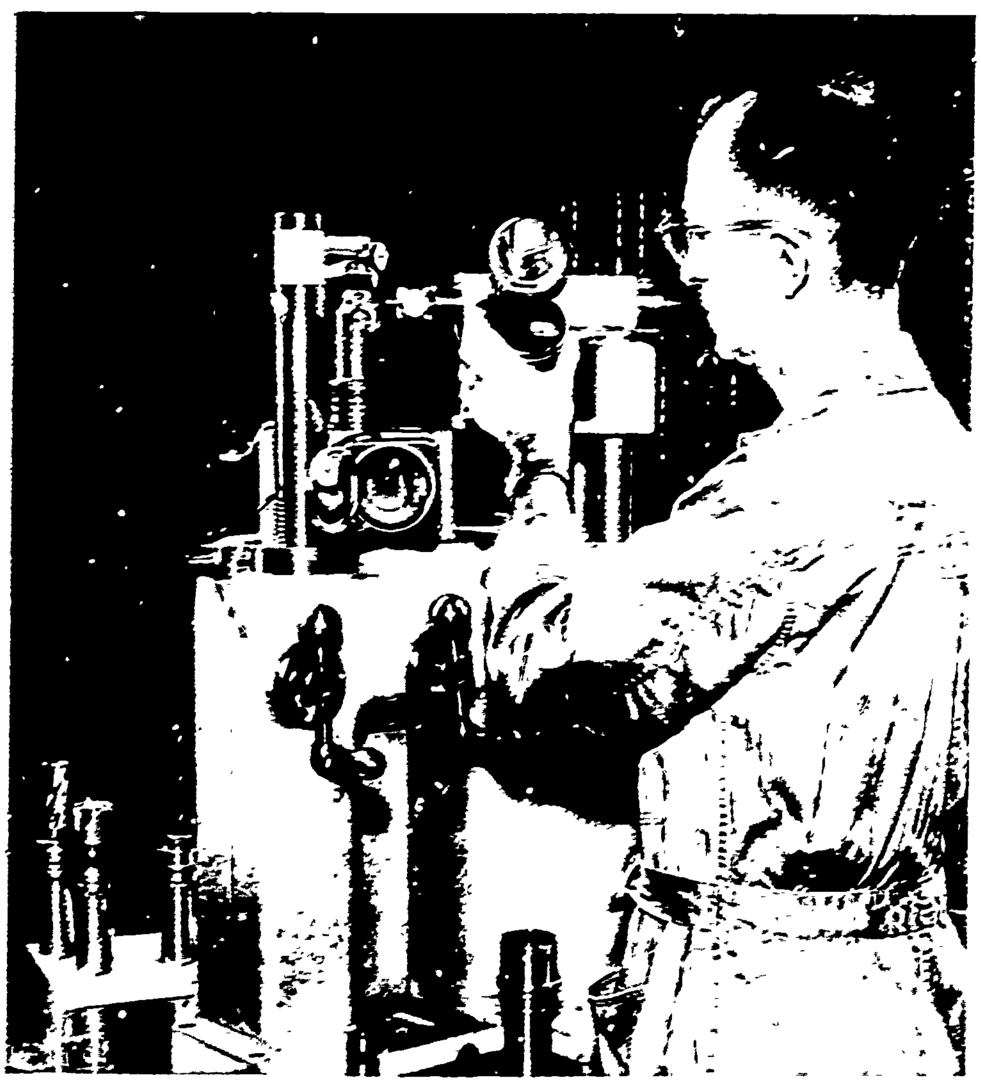
completion of school courses in mechanical drawing as evidence of adequate mechanical and other aptitudes for this, as well as many other shop jobs. Ability—and willingness—to read and follow detailed instructions exactly, are essential to adequate job performance. Training time varies widely, because of varying background of workers selected for training, and range of complexity of presetting instruments in use.

Some background in use of inspection instruments is regarded as particularly desirable: many tool presetting gages and instruments are adaptations of conventional inspection devices to meet the new purpose, rather than completely new instruments. Thus persons with experience in shop inspection, or in checking out their own work as machine hands, normally require less extensive training to become competent in tool presetting.

WORKER TRAITS

Aptitudes:

Verbal ability to read written and oral instructions, and abbreviations, and to communicate with supervisor about problems, such as lack of specified tooling and need to improvise from other components.



Numerical ability at level of decimal arithmetic to comprehend presetting instructions, interpret scales and gages, and code tooling for numerically controlled automatic-tool-changing machine tools.

Spatial ability to visualize components and assembled, composite tooling from tool layup sketches and written specifications.

Clerical perception to note pertinent detail in printed and written instructions, and to compare visual indications of tooling dimensions with original data, in order to detect errors.

Motor coordination and manual and finger dexterity to assemble, and preset tooling accurately with use of gages and presetting instruments. Must work rapidly to adhere to schedules, to permit minimum tooling inventory and prevent unnecessary machine downtime.

Interests:

An interest in activities concerned with machines, processes and techniques to use a wide range of tool presetting gages and instruments.

A preference for activities of a routine and organized nature to follow detailed tool layup instructions.

Temperaments:

Must adjust to working within prescribed tolerances, with zero-error standards of performance applicable; an error can cause scrapping of workpiece, damage to fixture or machine tool, or even severe injury to a machine tool operator.

Physical Demands and Working Conditions:

Work is light, lifting tooling and manually positioning and assembling cutting tools, holders and extensions, seldom weighing more than 20 pounds. Has helper, or uses hand hoist or job crane, when handling heavy, oversize tooling.

Walks intermittently within work station which may be in central toolroom, tool crib, or area adjacent to numerically controlled machine tools, to select and organize tooling components.

Reaching, handling, fingering and feeling, to work with precision gages and controls of presetting machines.

Near visual acuity and accommodation, to read manuscripts, charts, and sketches, and use gages and presetting instruments.

Work is performed inside.

VERTICAL TURRET LATHE OPERATOR, NUMERICAL CONTROL

609.382

vertical boring mill operator, numerical control

OCCUPATIONAL DEFINITION

Sets up and operates numerically controlled vertical turret lathes, to bore, turn, and face complex workpieces: Studies process sheets, blueprints, and tooling specifications and charts to determine sequence of operations, organize work activities, and set machine controls. Attaches chucks or blocks to machine table, or attaches fixtures as specified on instructions, by use of wrenches. Signals crane operator and instructs crane helpers, or uses hoist to position large-diameter workpiece, and shims until level. Secures workpiece to fixtures and machine table by using wrenches. Reads micrometer dials and uses Allen wrenches to set tool stops at positions specified on setup instructions. Loads and fastens preset tooling in turret and ram heads on crossrail and sideheads. Inserts tape in read unit, and turns and depresses switches to bring head into position, sets machine zero point and initiates first cut.

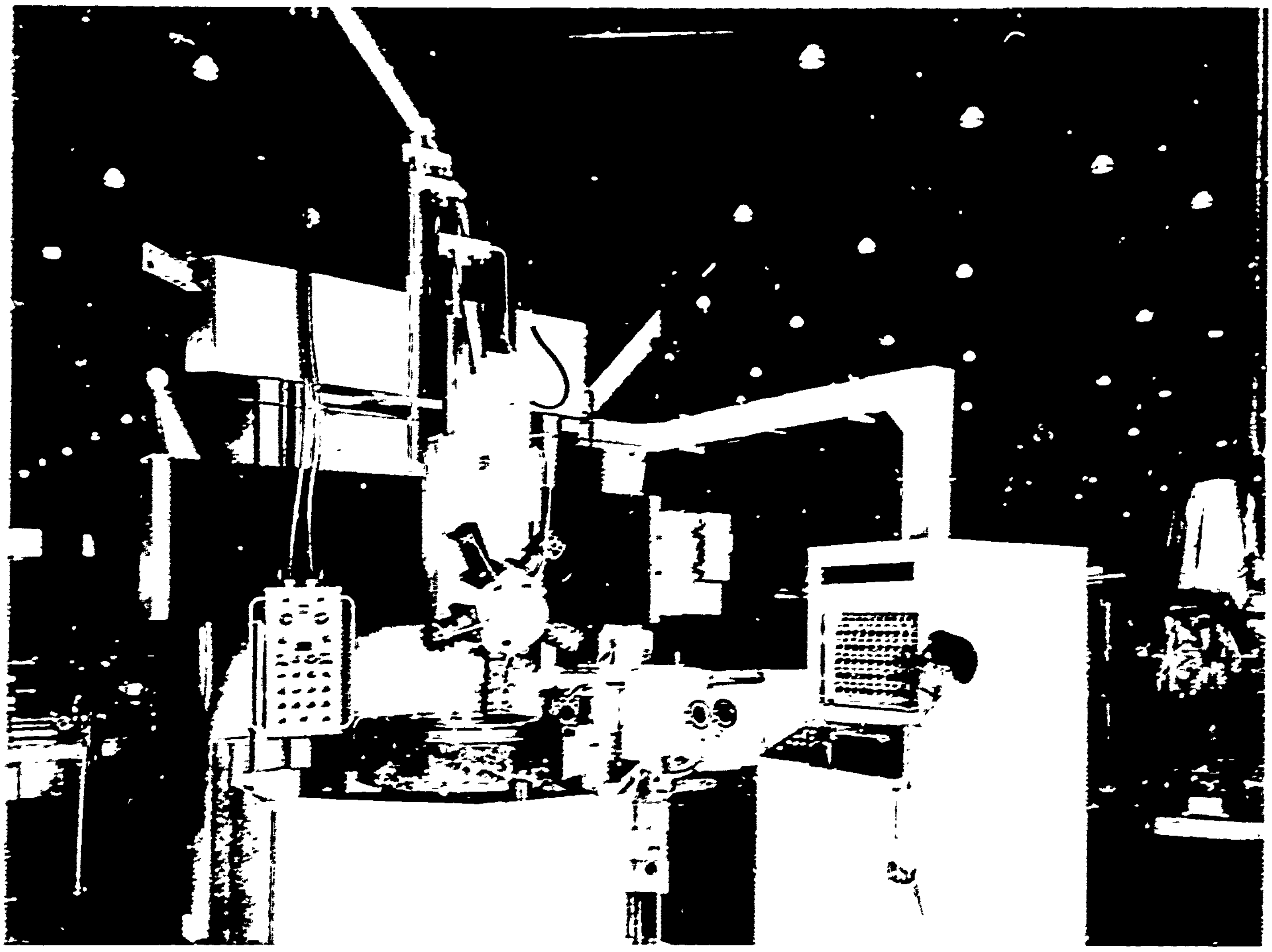
Inspects each cut of first workpiece, using micrometers and gages, and applies knowledge of machining practices to compensate for such factors as tool deflection, misalignment and wear on succeeding pieces, by turning tool offset dials on control console. Repeats cut, by depressing repeat button, to attain specified dimensions. Removes and replaces workpieces at end of machining cycles. Monitors full-automatic operation of machine on subsequent workpieces of production run, and adjusts controls such as feedrate and tool offset dials in order to compensate for workpiece hardness and size variation. Notifies foreman of operation difficulties, of any action taken to override tape, and reason for overriding. Assembles tools, holders and extensions for next job, presets tooling off machine, on tool setting gage, and spot-inspects and deburrs parts while machine operates automatically, in order to reduce machine downtime.

May keep written records of operating and downtime, and of changes in machine and tool settings required to produce parts satisfactorily. May operate machine on dry run before machining first piece with unproven tape, by comparing machine moves to manuscript and console display data, in order to detect gross positioning errors in part program. May operate machine manually by methods similar to conventional machine operation, to incorporate changes in standard-part tape, or when part program and tape have not been prepared.

EDUCATION, TRAINING, AND EXPERIENCE

High school or vocational school graduate preferred, with courses in the machine trades. Because of machine and workpiece size and complexity,[1] many employers require trainees to have had one to two years

[1] Vertical turret lathe and boring mill workpieces normally are large and complex. They can be awkward to handle, and to set tooling for, because of irregular shape or overhangs. Because of this, or the way the job must be run because of machine design, the operator sometimes has to exercise considerable ingenuity in inspecting his workpieces. A considerable variation in workpiece size—and hardness—is typical of parts to be produced on these machines. Thus, many employers prefer to assign operators with extensive training and experience on conventional machines so they can better recognize potential machining problems. Often, these men are given full authority to override the tape. Some positioning-type machines have as many as fifty trimmings potentiometers (trim-pots) that are used to compensate for such factors as tool wear, deflection and misalignment on repeat operations.



Vertical Turret Lathe

or more of on-the-job, short-run work experience on other conventional machine tools, including radial drill presses and/or horizontal boring machines. Some employers require completion of machinist apprenticeship or equivalent in experience, because of machine versatility, and wide range of machining problems that are encountered when performing multiple and often simultaneous operations on large-diameter workpieces. Extensive shop background is regarded as especially necessary when the operator is required to do considerable prototype machining, and when he operates machine-and-control systems capable of contouring, or threading and taper turning.

WORKER TRAITS

Aptitudes:

Verbal ability to comprehend written setup and operating instructions, and explain operating problems and malfunctions to foreman, maintenance and part programing personnel.

Numerical ability at level of arithmetic, to add and subtract decimals in order to inspect parts—scratchpad computations are necessary when indirect measurements have to be taken. Division of decimals by two is required to set dial-type trimming potentiometers accurately. While not always a requirement, an understanding of binary mathematics is almost necessary to understand how the numerical control system operates, explain operating difficulties, and interpret binary-coded-decimal tape commands. This can be learned on the job, however, and most operators keep a conversion chart in their machine area, so it is available for ready reference, to identify tape feeds, speeds, and position commands.

Spatial ability to interpret tool layup drawings, and part blueprints and sketches.

Clerical perception to perceive pertinent detail in written setup and operating instructions, and recognize alphabetic and numeric symbols.

Manual dexterity to use inspection and tool setting instruments, and handtools.

Interests:

A preference for working with machines and processes to set up, operate, and monitor the equipment that comprises the machine-and-control system.

Interest in activities of a concrete and organized nature to operate machine according to specific, detailed, and sequential instructions.

Temperaments:

Must adjust to a variety of tasks requiring frequent change during time machine is operating under tape control, to hold machine downtime for inspection checks and change-overs to a minimum.

Must have disposition to follow, without deviation, written instructions, charts, and tooling sketches, that not only describe his work activities but often prescribe the sequence in which they must be performed.

Physical Demands and Working Conditions:

Strength requirement is medium, involving infrequent stooping or crouching when setting up and inspecting workpiece. Lifts, inserts and secures cutting tools, clamps, and risers seldom exceeding 30 pounds.

Stands and walks frequently when monitoring machine.

Near visual acuity and accommodation to follow detailed process manuscript, monitor machine performance, and interpret lights and sequence number displays on control console.

Work is performed inside.

DEFINITIONS OF WORKER TRAITS

DEFINITIONS OF WORKER TRAITS

APTITUDES: Specific capacities and abilities required of an individual in order to learn or perform adequately a task or job duty.

INTELLIGENCE: General learning ability. The ability to "catch on" or understand instructions and underlying principles. Ability to reason and make judgments. Closely related to doing well in school.

VERBAL: Ability to understand meanings of words and ideas associated with them, and to use them effectively. To comprehend language, to understand relationships between words, and to understand meanings of whole sentences and paragraphs. To present information or ideas clearly.

NUMERICAL: Ability to perform arithmetic operations quickly and accurately.

SPATIAL: Ability to comprehend forms in space and understand relationships of plane and solid objects. May be used in such tasks as blueprint reading and in solving geometry problems. Frequently described as the ability to "visualize" objects of two or three dimensions, or to think visually of geometric forms.

FORM PERCEPTION: Ability to perceive pertinent detail in objects or in pictorial or graphic material; to make visual comparisons and discriminations and see slight differences in shapes and shadings of figures and widths and lengths of lines.

CLERICAL PERCEPTION: Ability to perceive pertinent detail in verbal or tabular material; to observe differences in copy, to proofread words and numbers, and to avoid perceptual errors in arithmetic computation.

MOTOR COORDINATION: Ability to coordinate eyes and hands or fingers rapidly and accurately in making precise movements with speed. Ability to make a movement response accurately and quickly.

FINGER DEXTERITY: Ability to move the fingers and manipulate small objects with the fingers rapidly or accurately.

MANUAL DEXTERITY: Ability to move the hands easily and skillfully. To work with the hands in placing and turning motions.

EYE-HAND-FOOT COORDINATION: Ability to move the hand and foot coordinately with each other in accordance with visual stimuli.

COLOR DISCRIMINATION: Ability to perceive or recognize similarities or differences in colors, or in shades or other values of the same color; to identify a particular color, or to recognize harmonious or contrasting color combinations, or to match colors accurately.

INTERESTS: Preferences for certain types of work activities or experiences, with accompanying rejection of contrary types of activities or experiences. Five pairs of interest factors are provided so that a positive preference for one factor of a pair also implies rejection of the other factor of that pair.

1. Situations involving a preference for activities dealing with things and objects.	vs.	6. Situations involving a preference for activities concerned with people and the communication of ideas.
2. Situations involving a preference for activities involving business contact with people.	vs.	7. Situations involving a preference for activities of a scientific and technical nature.
3. Situations involving a preference for activities of a routine, concrete, organized nature.	vs.	8. Situations involving a preference for activities of an abstract and creative nature.
4. Situations involving a preference for working for people for their presumed good, as in the social welfare sense, or for dealing with people and language in social situations.	vs.	9. Situations involving a preference for activities that are nonsocial in nature, and are carried on in relation to processes, machines, and techniques.
5. Situations involving a preference for activities resulting in prestige or the esteem of others.	vs.	0. Situations involving a preference for activities resulting in tangible, productive satisfaction.

TEMPERAMENTS: Different types of occupational situations to which workers must adjust.

1. Situations involving a variety of duties often characterized by frequent change.
2. Situations involving repetitive or short cycle operations carried out according to set procedures or sequences.
3. Situations involving doing things only under specific instruction, allowing little or no room for independent action or judgment in working out job problems.
4. Situations involving the direction, control, and planning of an entire activity or the activities of others.
5. Situations involving the necessity of dealing with people in actual job duties beyond giving and receiving instructions.
6. Situations involving working alone and apart in physical isolation from others, although the activity may be integrated with that of others.
7. Situations involving influencing people in their opinions, attitudes, or judgments about ideas or things.

8. Situations involving performing adequately under stress when confronted with the critical or unexpected or when taking risks.

9. Situations involving the evaluation (arriving at generalizations, judgments, or decisions) of information against sensory or judgmental criteria.

0. Situations involving the evaluation (arriving at generalizations, judgments, or decisions) of information against measurable or verifiable criteria.

X. Situations involving the interpretation of feelings, ideas, or facts in terms of personal viewpoint.

Y. Situations involving the precise attainment of set limits, tolerances, or standards.

PHYSICAL DEMANDS: Those physical activities required of a worker in a job. The physical demands referred to serve as a means of expressing both the physical requirements of the job and the physical capacities (specific physical traits) a worker must have to meet the requirements.

1. Lifting, Carrying, Pushing, and/or Pulling (Strength). These are the primary "strength" physical requirements, and generally speaking, a person who engages in one of these activities can engage in all. Specifically, each of these activities can be described as:

(1) **Lifting:** Raising or lowering an object from one level to another (includes upward pulling).

(2) **Carrying:** Transporting an object, usually holding it in the hands or arms or on the shoulder.

(3) **Pushing:** Exerting force upon an object so that the object moves away from the force (includes slapping, striking, kicking, and treadle actions).

(4) **Pulling:** Exerting force upon an object so that the object moves toward the force (includes jerking).

The five degrees of this factor (Lifting, Carrying, Pushing, and/or Pulling) are:

Sedentary Work: Lifting 10 lbs. maximum and occasionally lifting and/or carrying such articles as dockets, ledgers, and small tools. Although a sedentary job is defined as one which involves sitting, a certain amount of walking and standing is often necessary in carrying out job duties. Jobs are sedentary if walking and standing are required only occasionally and other sedentary criteria are met.

Light Work: Lifting 20 lbs. maximum with frequent lifting and/or carrying of objects weighing up to 10 lbs. Even though the weight lifted may be only a negligible amount, a job is in this category when it requires walking or standing to a significant degree, or when it involves sitting most of the time with a degree of pushing and pulling of arm and/or leg controls.

Medium Work: Lifting 50 lbs. maximum with frequent lifting and/or carrying of objects weighing up to 25 lbs.

Heavy Work: Lifting 100 lbs. maximum with frequent lifting and/or carrying of objects weighing up to 50 lbs.

Very Heavy Work: Lifting objects in excess of 100 lbs. with frequent lifting and/or carrying of objects weighing 50 lbs. or more.

2. Climbing and/or Balancing.

(1) **Climbing:** Ascending or descending ladders, stairs, scaffold-

ing ramps, poles, ropes, and the like, using the feet and legs and/or hands and arms.

(2) **Balancing:** Maintaining body equilibrium to prevent falling when walking, standing, crouching, or running on narrow, slippery, or erratically moving surfaces; or maintaining body equilibrium when performing gymnastic feats.

3. **Stooping, Kneeling, Crouching, and/or Crawling.**

(1) **Stooping:** Bending the body downward and forward by bending the spine at the waist.

(2) **Kneeling:** Bending the legs at the knees to come to rest on the knee or knees.

(3) **Crouching:** Bending the body downward and forward by bending the legs and spine.

(4) **Crawling:** Moving about on the hands and knees or hands and feet.

4. **Reaching, Handling, Fingering, and/or Feeling.**

(1) **Reaching:** Extending the hands and arms in any direction.

(2) **Handling:** Seizing, holding, grasping, turning, or otherwise working with the hand or hands (fingering not involved).

(3) **Fingering:** Picking, pinching, or otherwise working with the fingers primarily (rather than with the whole hand or arm, as in handling).

(4) **Feeling:** Perceiving such attributes of objects and materials as size, shape, temperature, or texture, by means of receptors in the skin, particularly those of the finger tips.

5. **Talking and/or Hearing.**

(1) **Talking:** Expressing or exchanging ideas by means of the spoken word.

(2) **Hearing:** Perceiving the nature of sounds by the ear.

6. **Seeing:** Obtaining impressions through the eyes of the shape, size, distance, motion, color, or other characteristics of objects.
The major visual functions are defined as follows:

(1) **Acuity, far:** clarity of vision at 20 feet or more
Acuity, near: clarity of vision at 20 inches or less.

(2) **Depth Perception:** three dimensional vision. The ability to judge distance and space relationships so as to see objects where and as they actually are.

(3) **Field of vision:** the area that can be seen up and down or to the right or left while the eyes are fixed on a given point.

(4) **Accommodation:** adjustment of the lens of the eye to bring an object into sharp focus. This item is especially important when doing near-point work at varying distances from the eye.

(5) **Color vision:** the ability to identify and distinguish colors.

WORKING CONDITIONS: the physical surroundings of a worker in a specific job. Also known as Environmental Conditions.

1. **Inside, Outside, or Both.**

   I Inside: Protection from weather conditions, but not necessarily from temperature changes.

   O Outside: No effective protection from weather.

   B Both: Inside and outside.

   A job is considered "inside" if the worker spends approximately 75 per cent or more of his time inside, and "outside" if he spends approximately 75 per cent or more of his time outside. A job is considered "both" if the activities occur inside or outside in approximately equal amounts.

2. **Extremes of Cold Plus Temperature Changes.**

   (1) **Extremes of Cold:** Temperature sufficiently low to cause marked bodily discomfort unless the worker is provided with exceptional protection.

   (2) **Temperature Changes:** Variations in temperature which are sufficiently marked and abrupt to cause noticeable bodily reactions.

3. **Extremes of Heat Plus Temperature Changes.**

   (1) Temperature sufficiently high to cause marked bodily discomfort unless the worker is provided with exceptional protection.

   (2) **Temperature Changes:** Same as 2. (2).

4. **Wet and Humid.**

   (1) **Wet:** Contact with water or other liquids.

   (2) **Humid:** Atmospheric condition with moisture content sufficiently high to cause marked bodily discomfort.

5. **Noise and Vibration.**

   Sufficient noise, either constant or intermittent, to cause marked distraction or possible injury to the sense of hearing and/or sufficient vibration (production of an oscillating movement or strain on the body or its extremities from repeated motion or shock) to cause bodily harm if endured day after day.

6. **Hazards.** Situations in which the individual is exposed to the definite risk of bodily injury.

7. **Fumes, Odors, Toxic Conditions, Dust, and Poor Ventilation.**

   (1) **Fumes:** Smoky or vaporous exhalations, usually odorous, thrown off as the result of combustion or chemical reactions.

   (2) **Odors:** Noxious smells, either toxic or nontoxic.

   (3) **Toxic Conditions:** Exposure to toxic dust, fumes, gases, vapors, mists, or liquids which cause general or localized disabling conditions as a result of inhalation or action on the skin.

   (4) **Dust:** Air filled with small particles of any kind, such as textile dust, flour, wood, leather, feathers, etc., and inorganic dust, including silica and asbestos, which make the workplace unpleasant or are the source of occupational diseases.

   (5) **Poor Ventilation:** Insufficient movements of air causing a feeling of suffocation; or exposure to drafts.

GLOSSARY

GLOSSARY

A

ACCURACY: The degree of exactness of an approximation or measurement. High accuracy thus implies low error. Accuracy normally denotes quality of computed results; precision usually refers to the amount of detail used in representing those results. Thus, four-place results are less precise than six-place results; nevertheless a four-place table might be more accurate than an erroneously computed six-place table.

ADAPTIVE CONTROL: Descriptive of systems which represent an extension of closed loop, feedback control, in that performance of the machine, process, or other controlled object is optimized, rather than merely corrected. At present state of development, most adaptive machine-tool controls are special-purpose systems which sense tool torque and optimize feedrates and speeds for small-hole drilling of extremely hard substances. Synonymous with self-optimizing control.

AUTOMATIC DRAFTING MACHINE: A sophisticated X-Y PLOTTER, usually used in conjunction with a computer, which produces graphic output from numerical input. Frequently capable of printing letters, numbers, and symbols as well as drawing and scribing lines and curves. Useful in areas such as design analysis, engineering mechanical drawing preparation, and cutter center-path verification for numerical machining. Contrasted with DIGITIZING MACHINE.

AUTOMATION: Production by devices or machines which are self-acting with respect to predetermined processes.

B

BASE-LINE DIMENSIONING: Descriptive of designing and part drawing technique of recording dimensions as distances from a base line, which may be outside the part, in order to reduce duplication of effort and simplify mathematical tasks of numerical control part programers.

BINARY: A characteristic, property, or condition in which there are but two possible alternatives; e.g., the binary number system using two as its base and using only the digits zero (0) and one (1).

BINARY CODE: (1) A coding system in which the encoding of any data is done through the use of bits; i.e., 0 or 1. (2) A code for the ten decimal digits, 0, 1, . . . , 9 in which each is represented by its binary, radix 2, equivalent; i.e., straight binary.

BINARY CODED DECIMAL: A decimal notation in which the individual decimal digits are represented by a pattern of ones and zeroes; e.g., in the 8-4-2-1 coded decimal notation, the number twelve is represented as 0001 0010 for 1 and 2, respectively, whereas in pure or straight binary notation it is represented as 1100.

BINARY CODED DECIMAL NOTATION: A method of representing each figure in a decimal number by a four-figured binary number.

BIT: (1) An abbreviation of binary digit. (2) A single character in a binary number. (3) A single pulse in a group of pulses. (4) A unit of information capacity of a storage device. The capacity in bits is the logarithm to the base two of the number of possible states of the device.

BLOCK COUNT READOUT: Optical numerical display of the number of control tape blocks processed by a numerical control system.

BOOLEAN ALGEBRA: A process of reasoning, or a deductive system

of theorems using a symbolic logic, and dealing with classes, propositions, or on-off circuit elements. It employs symbols to represent operators such as AND, OR, NOT, EXCEPT, IF . . . THEN, to permit mathematical calculation. Named after George Boole, famous English mathematician (1815-1864).

BORING: Finishing a hole already drilled or cored, by means of a rotating, offset, single-point tool. On some boring machines the tool is stationary and the work revolves; on others the reverse is true.

C

CARD-TO-TAPE CONVERTER: A device which converts information directly from punched cards to punched or magnetic tape.

CARTESIAN COORDINATE: (1) The distance of a point from either of two intersecting straight-line axes measured parallel to the other axis. (2) The distance from any of three intersecting coordinate planes measured parallel to that one of three straight-line axes that is the intersection of the other two planes.

CASCADE CONTROL: An automatic control system in which various control units are linked in sequence, each control unit regulating the operation of the next control unit in line.

CHIPMAKING: The cutting away of excess metal, in the form of chips, from a workpiece by use of a cutting tool. Differentiated from abrading or grinding because of the larger sizes of chips removed and by higher metal-removal rates.

CLOSED LOOP: Pertaining to a system with feedback type of control, such that the output is used to modify the input.

COMMAND: (1) An electronic pulse, signal or set of signals to start, stop or continue some operation. It is incorrect to use command as a synonym for instruction. (2) The portion of an instruction word which specifies the operation to be performed.

COMPUTER: A device capable of accepting information, applying prescribed processes to the information, and supplying the results of these processes. It usually consists of input and output devices, storage, arithmetic, and logical units, and a control unit.

CONTOUR CONTROL SYSTEM: A numerical control system in which the cutting path of each tool can result from the coordinated, simultaneous motion of two or more axes. Descriptive of the most complex category of machine tool numerical control systems. Contrasted with POSITION CONTROL SYSTEM and STRAIGHT-CUT CONTROL SYSTEM.

D

DAMPING: A characteristic built into electrical circuits and mechanical systems to prevent rapid or excessive corrections which may lead to instability or oscillatory conditions; e.g., connecting a register on the terminals of a pulse transformer to remove natural oscillations or placing a moving element in oil or sluggish grease to prevent mechanical overshoot of the moving parts.

DEBUG: (1) To locate and correct any errors in a computer program or part program. (2) To detect and correct malfunctions in a computer, control system, or machine.

DECADE: A group or assembly of ten units; e.g., a counter which counts to ten in one column or a resistor box which inserts resistance quantities in multiples of powers of 10.

DIGITAL COMPUTER: A computer which processes information represented by combinations of discrete or discontinous data as compared with an analog computer for continuous data. More specifically, it is a device for performing sequences of arithmetic and logical operations, not only on data but its own program. Still more specifically it is a stored program digital computer capable of performing sequences of internally stored instructions, as opposed to calculators, such as card programed calculators, on which the sequence is impressed manually.

DIGITIZER: A device which converts an analog measurement into digital form. Synonymous with quantizer.

DIGITIZING MACHINE: A machine, similar in appearance to AUTOMATIC DRAFTING MACHINE, which senses lines and curves on graphic input, such as an engineering mechanical drawing, and converts to numerical tape and/or printed output. May be operated by programing personnel who type in auxiliary machine-tool commands for merger with geometric data such as cutter center-paths, to produce complete machine control tapes for numerical machining. May be AUTOMATIC DRAFTING MACHINE with additional equipment which permits digitizing.

DOWNTIME: The period during which a system, computer, or any other device is malfunctioning or not operating, due to electronic, mechanical, or other inherent failure.

DRILLING: Cutting a round hole by means of a rotating drill.

E

ELECTRONIC: Pertaining to that branch of science which deals with the motion, omission, and behavior of currents of free electrons, especially in vacuum, gas, or phototubes and special conductors or semiconductors. This is contrasted with electric which pertains to the flow of large currents in metal conductors.

ELECTRONIC DATA PROCESSING SYSTEM: The general term used to define a system for data processing by means of machines utilizing electronic circuitry at electronic speed, as opposed to electromechanical equipment.

ELECTRONIC SWITCH: A circuit element causing a start and stop action or a switching action electronically, usually at high speed.

ERROR: The general term referring to any deviation of a computed or a measured quantity from the theoretically correct or true value.

F

FEEDBACK: The part of a closed loop system which automatically brings back information about the condition under control.

FEEDBACK CONTROL: A type of system control obtained when a portion of the output signal is operated upon and fed back to the input in order to obtain a desired effect.

FEEDBACK CONTROL SIGNAL: That portion of the output signal which is returned to the input in order to achieve a desired effect, such as a fast response.

FIXED WORD-LENGTH: Having the property that a machine word always contains the same number of characters or digits. Contrasted with VARIABLE WORD-LENGTH.

FLOATING ZERO: Descriptive of a feature of some numerical machine

controls, by which the zero point on a machine axis can be shifted; the control system retains no data concerning previous machine zero points. Contrasted with ZERO OFFSET.

FORTRAN: A programing language designed for problems which can be expressed in algebraic notation, allowing for exponentiation and up to three subscripts. The FORTRAN compiler is a routine for a given machine which accepts a program written in FORTRAN source language and produces a machine language routine object program. FORTRAN II added considerably to the power of the original language by giving it the ability to define and use almost unlimited hierarchies of sub-routines, all sharing a common storage region if desired. Later improvements have added the ability to use Boolean expressions, and some capabilities for inserting symbolic machine language sequences within a source program.

G

GATE: A circuit which yields an output signal that is dependent on some function of its present or past input signals.

GRAPHIC PANEL: A master control panel which, pictorially and usually colorfully, traces the relationship of control equipment and the process operation. It permits an operator at a glance, to check on the operation of a far flung control system by noting dials, valves, scales, and lights.

H

HEAD: A device which reads, records or erases information in a storage medium, usually a small electromagnet used to read, write or erase information on a magnetic drum or tape or the set of perforating or reading fingers and block assembly for punching or reading holes in paper tape or cards.

HOLOGRAPHY: Descriptive of types of photography or wave-front reconstruction, not employing lenses, in which interference patterns rather than conventional images are recorded, and in which a coherent light source is used to reconstruct data from photographic, radar, or other acquisition systems in apparent three-dimensional form.

HUNTING: A continuous attempt on the part of an automatically controlled system to seek a desired equilibrium condition. The system usually contains a standard, a method of determining deviation from this standard, and a method of influencing the system such that the difference between the standard and the state of the system is brought to zero. Clarified by SERVOMECHANISM.

HYSTERISIS: The lagging in the response of a unit of a system behind an increase or decrease in the strength of a signal.

I

INFORMATION THEORY: The mathematical theory concerned with information rate, channels, channel width, noise and other factors affecting information transmission. Initially developed for electrical communications, it is now applied to business systems, and other phenomena which deal with information units and flow of information in networks.

INTEGRATED PLANT CONTROL SYSTEM: Descriptive of potential extension of process control systems, in which a large-scale digital computer system controls the totality of a processing or manufacturing plant on a closed loop, real time basis, automatically gathering and analyzing data, and executing programed management decisions.

L

LAG: A relative measure of the time delay between two events, states, or mechanisms.

LOGGER: A device which automatically records physical process and events, usually chronologically.

LOGIC: (1) The systematic scheme which defines the interactions of signals in the design of an automatic data processing system. (2) The basic principles and application of truth tables and inter-connection between logical elements required for arithmetic computation in an automatic data processing system.

M

MACHINABILITY: Descriptive of the quality or state of being machinable. Machinability rating assists in selecting appropriate machine feedrates and cutting speeds.

MAGNETIC TAPE: A tape or ribbon of any material impregnated or coated with magnetic or other material on which information may be placed in the form of magnetically polarized spots.

MILLING: Machining a piece of metal by bringing it into contact with a rotating cutting tool having multiple cutting edges. A narrow milling cutter resembles the circular saw. Other cutters may have spiral edges which gives the appearance of a huge screw. Some of the shapes produced by milling machines are very simple like the slots and surfaces produced by a circular saw; other shapes may consist of a variety of combinations of flat and curved surfaces, depending on the shape given to the cutting edges of the tools.

MIX: The total range of manufactured products produced by a business establishment or portion of it.

MODULE: (1) An interchangeable plug-in item containing components. (2) An incremental block of storage, or other building block, for expanding the capacity of a computer or other electronic system.

N

NOISE: The meaningless extra bits or words which must be ignored or removed from the data at the time the data is used.

NUMERICAL CONTROL: Descriptive of concepts and systems related to control of object action by direct insertion of numerical data rather than by physical means. Synonymous with symbolic control. See NUMERICAL CONTROL SYSTEM.

NUMERICAL CONTROL SYSTEM: A system in which actions are controlled by the direct insertion of data at some point, and in which the system must automatically interpret some portion of this data. Application of term usually is restricted to description of a system for the control of discrete, rather than continuous-flow processes; thus, contrasted with PROCESS CONTROL. See CONTOUR CONTROL SYSTEM, POSITION CONTROL SYSTEM, and STRAIGHT-CUT CONTROL SYSTEM.

O

ON-LINE: Descriptive of a system and of the peripheral equipment or devices in a system in which the operation of such equipment is under control of the central processing unit, and in which information reflecting current activity is introduced into the data processing system as soon as it occurs, thus, directly in-line with the main flow of transaction processing.

OPEN LOOP: Pertaining to a control system in which there is no self-correcting action for misses of the desired operational condition, as there is in a closed loop system.

P

PAPER TAPE: A strip of paper capable of storing or recording information. Storage may be in the form of punched holes, partially punched holes, carbonization or chemical change of impregnated material, or by imprinting. Some paper tapes, such as punched paper tape, are capable of being read by the input device of a computer or a transmitting device by sensing the pattern of holes which represent coded information.

PHOTOGRAMMETRY: The application of methods and techniques of photogrammetry to develop computer-oriented systems for automatic analysis, and description in symbolic numerical form, of complex geometric shapes such as die cavities and automobile mock-ups.

POLAR COORDINATE: Either of two numbers that locate a point in a plane by its distance from a fixed point on a line and the angle this line makes with a fixed line.

POSITION CONTROL SYSTEM: A discrete (noncontinuous) numerical control system in which end points are controlled, but transition paths to achieve them are not controlled; least complex of machine tool numerical control systems and frequently installed on drilling and boring machines. Contrasted with CONTOUR CONTROL SYSTEM and STRAIGHT-CUT CONTROL SYSTEM.

POSITION READOUT: Optical numerical display of absolute position of machine axis.

POST PROCESSOR: A computer program which converts the generalized output of a computer-processed part program into the specific input requirements o ˈe machine tool-numerical control system on which the part is to be mach. ed.

PROCESS CONTROL: Descriptive of systems in which digital, analog or hybrid computers are used for the automatic regulation of operations or processes. Typical are operations in the production of chemicals wherein the operation control is applied continuously and adjustments to regulate the operation are directed by the computer to keep the value of a controlled variable constant.

PROGRAM CONTROL: Descriptive of a system in which a computer is used to direct an operation or process and automatically to hold or to make changes in the operation or process on the basis of a prescribed sequence of events.

PULSE: A significant and sudden change of short duration in the level of some electric variable, usually voltage.

PROGRAM STOP: A stop instruction built into the program that will automatically stop a machine under certain conditions, or upon reaching the end of the processing, or completing the solution of a problem.

PUNCH CARD: A heavy stiff paper of constant size and shape, suitable for punching in a pattern that has meaning, and for being handled mechanically. The punched holes are sensed electrically by wire brushes, mechanically by metal fingers, or photoelectrically by photocells.

PUNCH TAPE: A tape, usually paper, upon which data may be stored in the form of punched holes. Hole locations are arranged in columns across the width of the tape. There are usually 5 to 8 positions (channels)

per column, with data represented by a binary coded decimal system. All holes in a column are sensed simultaneously in a manner similar to that for punch cards. Synonymous with perforated tape.

R

READOUT: A device that displays, in digits, data computed or recorded.

S

SYSTEMS TEST: (1) The running of the whole system against test data. (2) A complete simulation of the actual running system for purposes of testing out the adequacy of the system. (3) A test of an entire interconnected set of components for the purpose of determining proper functioning and interconnection.

T

TAPPING: Cutting a thread inside the hole so that a cap screw may be used in it.

TOOL MAGAZINE: A storage unit on a machine tool, from which tooling is withdrawn and replaced by an automatic tool-changing mechanism.

TRANSISTOR: An electronic device utilizing semiconductor properties to control the flow of currents.

TURNING: Performed on a lathe. Using an engine lathe, the piece of metal to be machined is rotated and the cutting tool pressed against it. Using a turret lathe (a lathe equipped with a six-sided toolholder called a turret, to which a number of different cutting tools are attached) several different cutting tools are brought into successive use, and the sequence of machining operations can be repeated over and over again without resetting the tools.

U

ULTRASONICS: The field of science devoted to frequencies of sound above the human audio range; i.e., above 20 kilocycles a second.

V

VARIABLE WORD-LENGTH: Having the property that a machine word may have a variable number of characters. Contrasted with FIXED WORD-LENGTH.

VECTOR: A quantity having magnitude and direction, as contrasted with a scaler which has quantity only.

VERIFIER: A device on which a record can be compared or tested for identity, character-by-character with a retranscription or copy as it is being prepared.

X-Y PLOTTER: A device used in conjunction with a computer to plot coordinate points in the form of a graph.

Z

ZERO OFFSET: Descriptive of a feature of some numerical machine controls, by which the zero point on a machine axis can be shifted, with the control system retaining data concerning the previous machine zero point. Contrasted with FLOATING ZERO.

ZERO POINT: The point from which a numerical control system relates other points. Synonymous with zero reference point.

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Electronics (bi-weekly), New York, McGraw-Hill Publishing Company.

Factory (monthly), New York, McGraw-Hill Publishing Company.

Industrial Machinery News (monthly), Detroit, Michigan, Samuel Schiff.

Information and Control (quarterly), New York, Academic Press, Inc.

Iron Age (weekly), Philadelphia, Pennsylvania, Chilton Company.

Machine and Tool Blue Book (monthly), Wheaton, Illinois, Hitchcock Publishing Company.

Machine Design (bi-weekly), Cleveland, Ohio, Penton Publishing Company.

Machinery (monthly), New York, Industrial Press.

Mechanical Engineering (monthly), New York, American Society of Mechanical Engineers.

Metalworking (monthly), Boston, Massachusetts, a Calners Publication.

Metalworking News (weekly), New York, Fairchild Publications, Inc.

Metlfax Magazine (monthly), Cleveland, Ohio, Fax Publications.

Mill and Factory (monthly), New York, Conover-Mast Publications, Inc.

Modern Machine Shop (monthly), Cincinnati, Ohio, Gardner Publications, Inc.

The Tool and Manufacturing Engineer (irregular), Dearborn, Michigan, The American Society of Tool and Manufacturing Engineers.

Tooling and Production (monthly), Cleveland, Ohio, Huebner Publications, Inc.

Western Machinery and Steel World (monthly), San Francisco, California, J. S. Hines Publishing.

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U. S. Department of Labor, Bureau of Labor Statistics, *Outlook for Numerical Control of Machine Tools,* Washington, D. C., U. S. Government Printing Office, 1965.

U. S. Department of Labor, Bureau of Labor Statistics, *Machining Occupations,* Occupational Outlook Report Series, Booklet No. 1450-45, Washington, D. C., U. S. Government Printing Office, 1966.

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How to Prove the Profit in Numerical Control, a series by American Machinist/Metalworking Manufacturing magazine.

Profits, Through Numerical Control, a series by Metalworking magazine.

Let's Discuss Numerical Control, by Modern Machine Shop magazine.

A large number of manufacturers of computer systems, numerical control machines, and controls have published materials, including audiovisual aids, suitable for such purposes as general orientation and classroom use. These manufacturers also are a source of information about special users' groups.

SOURCES OF ADDITIONAL INFORMATION

The organizations, schools, colleges, and universities listed below may be contacted for further academic, technical, or employment information. Even when organizations do not have a program of publication for external distribution, it frequently is possible to obtain information from individual members of special subsections, and regional or local chapters. This list is not an exhaustive one and is offered as a guide.

Organizations

American Association of Junior Colleges, 1777 Massachusetts Avenue N.W., Washington, D.C., 20036

American Federation of Technical Engineers, 900 F Street N.W., Washington, D.C., 20004

American Institute for Design and Drafting, 18465 James Couzens, Detroit, Mich., 48235

American Institute of Industrial Engineers, 345 East 47th Street, New York, N.Y., 10017

American Mathematical Society, 190 Hope Street, Providence, R.I., 02906

American Society of Mechanical Engineers, 345 East 47th Street, New York, N.Y., 10017

American Society of Tool and Manufacturing Engineers, 10700 Puritan Avenue, Detroit, Mich., 48238

Association for Computing Machinery, 211 East 43rd Street, New York, N.Y., 10017

Association of Data Processing Service Organizations, 947 Old York Road, Abingdon, Pa., 19001

Business Equipment Manufacturers' Association, 235 East 42nd Street, New York, N.Y., 10017

American Society for Engineering Education, Technical Institute Division, University of Illinois, Urbana, Ill., 61801

American Society for Metals, Metals Park, Ohio

Industrial Management Society, 330 South Wells Street, Chicago, Ill., 60606

Institute of Electrical and Electronic Engineers, 345 East 47th Street, New York, N.Y., 10017

Instrument Society of America, Penn-Sheraton Hotel, 530 William Penn Place, Pittsburgh, Pa., 15260

International Association of Machinists, 1300 Connecticut Avenue N.W., Washington, D.C., 20036

Mathematical Association of America, University of Buffalo, Buffalo, N.Y., 14214

National Association of Manufacturers, 2 East 48th Street, New York, N.Y., 10017

National Council of Technical Schools, 1507 M Street N.W., Washington, D.C., 20005

National Home Study Council, 1601 18th Street N.W., Washington, D.C., 20009

Engineers' Council for Professional Development, 345 East 47th Street, New York, N.Y., 10017

Engineers Joint Council, 345 East 47th Street, New York, N.Y., 10017

National Joint Apprenticeship and Training Committee for the Electrical Industry, 1200 18th Street N.W., Washington, D.C., 20036

National Machine Tool Builders' Association, 2139 Wisconsin Avenue N.W., Washington, D.C., 20007

National Referral Center for Science and Technology, Library of Congress, Washington, D.C., 20540

National Tool, Die, and Precision Machining Association, 907 Public Square Building, Cleveland, Ohio, 44113

Numerical Control Society, 122 East 42nd Street, New York, N.Y., 10017

Society for the Advancement of Management, Inc., 16 West 40th Street, New York, N.Y., 10018

U.S. Chamber of Commerce, 1615 H Street N.W., Washington, D.C., 20006

'ocational, Technical and Adult Schools, Colleges and Universities

California Institute of Technology, Pasadena, California

California State Polytechnic College, Machine Shop Department, San Luis Obispo, California

Carnegie Institute of Technology, Pittsburgh, Pennsylvania

Fond du Lac Vocational, Technical and Adult Schools, Fond du Lac, Wisconsin

Green Bay Vocational, Technical and Adult Schools, Green Bay, Wisconsin

Illinois Institute of Technology, Chicago, Illinois

Madison Vocational, Technical and Adult Schools, Madison, Wisconsin

Massachusets Institute of Technology, Cambridge, Massachusetts

Milwaukee School of Engineering, Milwaukee, Wisconsin

Milwaukee Vocational, Technical and Adult Schools, Milwaukee, Wisconsin

Purdue University, Lafayette, Indiana

University of Wisconsin, Madison, Wisconsin

West Allis School of Vocational, Technical and Adult Education, West Allis, Wisconsin

Wisconsin School of Electronics, Madison, Wisconsin

ALPHABETICAL INDEX OF TITLES

The titles listed, all in alphabetical order, are presented in three forms:

- All capital letters—main titles identifying the job.
- All lower case letters—alternate or synonym titles, by which a job is also known.
- Initial capital letters—related titles. These are self-descriptive variations of the jobs they are associated with.

SELECTED OCCUPATIONAL INFORMATION PUBLICATIONS

Publications may be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Remittance in the form of check or money order payable to the Superintendent of Documents must accompany all orders. Do not send postage stamps.

1. CAREER GUIDE FOR DEMAND OCCUPATIONS. 1965. 40 pp. $.30 Provides information on education, training and worker trait requirements for 71 occupations in demand; also a bibliography of selected references.

2. DICTIONARY OF OCCUPATIONAL TITLES, in two volumes. Volume I. 1965. 809 pp. $5.00. Lists in alphabetical order over 35,000 job titles in the American economy Provides definitions for almost 22,000 individual occupations.

   Volume II. 1965. 656 pp. $4.25. Presents the occupational classification structure of the U.S. Employment Service. The structure consists of two arrangements of jobs. The first arrangement groups job according to a combination of work field, purpose, material, product, subject matter, generic term, and/or industry. The second arrangement groups jobs according to abilities and traits required of workers. Also arrays jobs according to industry.

   SELECTED CHARACTERISTICS OF OCCUPATIONS (PHYSICAL DEMANDS, WORKING CONDITIONS, TRAINING TIME) A SUPPLEMENT TO THE DICTIONARY OF OCCUPATIONAL TITLES, THIRD EDITION. 1966. 280 pp. $2.75. Lists individual physical demands, working conditions, and training time data for all jobs defined in the Dictionary. The information provides additional source material for determining job relationships in such activities as vocational counseling, personnel and manpower activities, training, rehabilitation, and placement.

3. GUIDE FOR ANALYZING JOBS, ANALYST'S WORKBOOK. Reprinted 1966. 40 pp. $.25. A companion, pocket-sized workbook to the TRAINING AND REFERENCE MANUAL FOR JOB ANALYSIS. Presents basic techniques of job analysis in outline form and provides an explanation of each job analysis component.

4. HEALTH CAREERS GUIDEBOOK. 1965. $1.50. Written and designed to appeal to young people who are interested in planning a career in the health field. Describes more than 200 jobs in this field and contains information about educational, training and licensing requirements; job prospects; salaries and working conditions; personal qualifications required; and sources of additional information.

5. JOB GUIDE FOR YOUNG WORKERS. 1963. 78 pp. $.45. Presents highlight information on entry jobs or fields of work frequently held by young people leaving high school. Provides information on employment prospects, qualifications for jobs, usual duties, characteristics of the jobs, and how and where jobs are obtained. Also directs the young job-seeker to Federal and State agencies which can provide job information and counseling. Includes selected readings and some tips on how to get a job.

6. OCCUPATIONS IN ELECTRONIC COMPUTING SYSTEMS. 1965. 72 pp. $.30. Describes 23 different occupations peculiar to electronic computing. Gives the education, training and characteristics required of the worker by the job, and lists the physical activities and environmental conditions usually encountered. Also has a glossary of technical terms, a bibliography, and a listing of organizations, colleges, and universities where additional information about electronic computing systems may be obtained.

7. OCCUPATIONS IN THE FIELD OF LIBRARY SCIENCE. 1966. 57 pp. $.30. Presents descriptive information about 22 occupations involved in library work, including education, training, and experience, and the worker traits required.

8. OCCUPATIONS IN THE CARE AND REHABILITATION OF THE MENTALLY RETARDED. 1966. 76 pp. $.35. Discusses the problems peculiar to the care and rehabilitation of those afflicted with mental retardation, and describes 27 occupations involved in such care and rehabilitation. Illustrated.

9. TECHNOLOGICAL CHANGES IN COMPOSING ROOM AND BINDERY PROCESSES IN THE PRINTING AND PUBLISHING INDUSTRY. 1964. 50 pp. A single copy, from a limited supply, is available, upon request, from the U.S. Employment Service, Bureau of Employment Security, U.S. Department of Labor, Washington, D.C. 20210. Presents a preliminary picture of occupational and staffing changes brought about in composing room and bindery processes as a result of the introduction of automated equipment or technological innovations. A limited study, covering eight plants in a single geographical area, and, therefore, not necessarily representative of the industry as a whole.

10. TRAINING AND REFERENCE MANUAL FOR JOB ANALYSIS. Interim Revision. 1965. 91 pp. $.60. An operational and reference text that presents the principles and practices for obtaining information about jobs.

11. TRAINING MANUAL FOR THE DICTIONARY OF OCCUPATIONAL TITLES (Third Edition): Part A, Instructor's Guide. 1965. 23 pp. $.25. Provides a guide to instructors for initiating and conducting the self-training program covering the Dictionary.
Part B, Trainee's Workbook. 1965. 323 pp. $1.75. A self-instructional text, presented in the form of a linear program, covering the contents, structure, arrangement, and use of the Dictionary.

Other occupational information publications prepared by the U.S. Employment Service are listed in a booklet titled BUREAU OF EMPLOYMENT SECURITY PUBLICATIONS, Section III, "Employment Service Publications." This booklet may be obtained without cost from the nearest local office of your State employment service or by writing to the U.S. Employment Service, Bureau of Employment Security, U.S. Department of Labor, Washington, D.C. 20210.

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